IMPROVING ACCESS TO THE APPOINTMENT
SYSTEM AT THE USAF MEDICAL CENTER
WRIGHT-PATTERSON AFB OH

THESIS

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THESIS

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of Systems and Logistics

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Master of Science in Information Resource Management

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Preface

This study sought to design a more efficient access method to the appointment system. Using the systematic approach of the design methodology, a single "best" solution was derived. Implementation of the proposed system will increase the availability of the appointment system to the patient, the true customer.

Like those before me, I could not have collected the information and wrote this thesis alone. I am most appreciative to my faculty advisor, Lt Col Dick Peschke, who "turned me on" to Ostrofsky's methodology and then guided me through the difficult periods of analysis with many helpful suggestions. Thanks goes to Major Don Shields of the Medical Center's office of Medical Computer Systems, whose concerns became this thesis and whose support provided timely inside information. I also wish to thank my wonderful wife Sandy whose encouragement, patience, and pioneering spirit helped me realize I could complete this work. I appreciate the forgiving nature of my children, Addie and Jonathan, who couldn't understand what Daddy was always doing, but knew he still loved them. Finally, I give thanks to the Creator who reminded me repeatedly that "all things are possible through Him who strengthens me."

R. Craig Ham

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Abstract

The purpose of this study was to select an optimal candidate system that would meet the needs identified. In the process the justification for selection was developed.

The study first conducted an indepth needs analysis of the problem, which was defined as the poor accessibility to the Medical Center appointment desk. Secondly, a feasibility study was completed that captured problem data and organized into a more meaningful analysis of the problem. Finally a preliminary activities phase established quantifiable criteria to assist in the selection of an optimal candidate system.

The methodology established 17 measurable parameters to quantify the criteria chosen. This quantification process assisted in the development of a single criterion function. The utilization of this function allowed for the selection of a single candidate system based on a cardinal scale. Sensitivity of the total criterion function value to each of the parameters was identified. Any changes to the chosen candidate system parameters should avoid affecting those parameters identified as having the greatest sensitivity.

The candidate system chosen relied on the use of an automated voice messaging system. A review of voice messaging technology showed the clear advantage this

communications application has. While no product endorsements were made, or suggested, Microlog Corporation's VCS 3000 automated voice messaging system was reviewed as an illustration of voice messaging equipment.

Recommendations included the need for further research that would improve other aspects of the appointment system. Duplication and verification of the study itself may improve the criteria selected and the choice of measurable parameters. Additional areas of research may also be directed toward the evaluation of available commercial voice messaging systems. Implementation of any particular system was not addressed but was assumed to a be a matter more appropriately left to the local commander's discretion.

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I. INTRODUCTION

General Issues

According to James Quinn, in an article for Scientific America, "efficient and high-quality services are crucial" to consumers (16:50). The services required of medical appointment scheduling rely on an effective system that stresses efficiency and quality goals. With the heavy daily demand for appointments, these goals can become a particular challenge for hospital appointment systems.

An effective appointment system will satisfy the needs of both staff and patients. To be efficient, the system should minimize the resources required to achieve optimal results. Various system configurations have been attempted in an effort to make appointment systems more effective and efficient.

Traditionally, appointments were scheduled using manual bookkeeping methods. For some situations this manual scheduling of appointments continues today but depending on patient volume, remains a tedious and time-consuming task. Automated systems, however, have been developed utilizing the computer's ability to efficiently handle routine and repetitive tasks. Although computers have simplified much

of the bookkeeping, the connection between the customer and the appointment system remains a human operator. It is through this mediator that patients gain access to the appointment desk and can then realize the benefits of computer efficiency.

As part of a hospital's overall goal, an effective appointment system can add substantially to a patient's satisfaction. When considering the need for an effective and efficient appointment system, one might consider the following French proverb: "While we keep a man waiting, he reflects on our shortcomings" (5:421).

Specific Problem

Patients seeking a routine or follow up appointment at the USAF Medical Center, Wright-Patterson AFB OH, must first contact the appropriate appointment desk either in person or by telephone. The Medical Center currently makes use of a de-centralized appointment process that delegates the responsibility of scheduling appointments to each individual department. The appointment system relies on a centralized appointment scheduling system that automates most of the bookkeeping efforts and integrates all subscribing departments with a single appointment scheduling software package and patient database.

If a patient calls an appointment desk and a connection is established, the call is either answered by an appoint-

ment clerk or put into a holding queue. Callers reaching a busy signal may need to re-dial several times until they are able to get through.

Several problems exist with such a system. The most apparent, are the inconvenience associated with having to re-dial a telephone number and the frustration encountered when placed on hold with no indication of duration. Major Donald Shields, Associate Administrator of Resources at the Medical Center, feels patient satisfaction could be greatly improved by reducing the amount of time a call stays in this waiting queue (22). Another problem is encountered when a call is connected and put on hold, no identification is given as to which appointment desk has been reached until the call is actually answered, the one exception being the pediatric clinic.

Finally, a significant problem exists with the absence of a mechanism to prioritize calls. This means routine appointment needs, acute care appointment needs, and information only calls are mixed together and responded to in a first-in-first-out (FIFO) manner. These problems all point to the need for a more efficient method of accessing the appointment scheduling desk.

Research Objectives

Based on the research design methodology developed by Benjamin Ostrofsky, University of Houston TX, a detailed examination of the problem was performed. The first three

steps in the methodology: Needs Analysis, Feasibility Study, and Preliminary Activities, were completed.

The first step, Needs Analysis, developed a statement of the specific problem based on the existing needs. The objective was to establish the need for the project and justify further research. Step two, the Feasibility Study, "developed a set of useful solutions to meet the needs" of the existing problem (14:29). This set of solutions was the result of an exhaustive review of potential methods that are available to satisfy the stated needs. Initially, no system was excluded simply because of operability or feasibility. The objective of the Feasibility Study was to acquire all possible ideas so as to eventually capture the one "best" candidate system that satisfies the needs of the original problem.

Finally, having developed a set of useful solutions, the last step addressed the Preliminary Activities. This analysis identified the best candidate system from the set of solutions originally considered. While the most theoretically favorable or optimum candidate system is desired, it may be necessary to settle for the optimal candidate system "which is the most favorable for the criteria and the set of candidates defined" (14:71). Ostrofsky advocates the formalism of the methodology as an objective approach which should result in a better

performing candidate system than what might "emerge from some other, less objective approach" (14:72).

While these activities may seem iterative in nature they lead up to the final objective which is the selection of the best possible solution to the problem identified. Obviously this "best" solution is dependant upon the information available and decisions made in the process of development. The resulting solution will meet the needs identified and be an effective choice for implementation.

Research Scope

The appointment system is a complex, interactive sequence of events. Within this flow of events are many subsystems, each having their own unique requirements. In a general sense, Brandler divides the appointment system into "appointment desk operations and appointment availability, [which] can be viewed as separate items for evaluation purposes" (3:25). As an existing subsystem, the problem with access to the appointment desk was further analyzed. In accordance with the prescribed methodology, a few of the suggested solutions may appear outlandish, but the likelihood of including the optimum candidate system increases with the inclusion of all possible solutions.

The USAF Medical Center at Wright-Patterson AFB is a large complex with a variety of departments and scheduling needs. Currently, the following departments fall under hospital services:

1. Dental Services
2. Environmental Health Service
3. Internal Medicine, including Neurology
4. Mental Health
5. Obstetrics and Gynecology
6. Orthopedics
7. Pediatrics
8. Primary or Acute Care
9. Radiology
10. Surgery

With the exception of Mental Health, Radiology, and Environmental Health Services, the remaining seven departments employ an automated appointment system that utilizes a centralized patient database. This study was concerned with patient access to the automated appointment system.

The final section in Ostrofsky's methodology delineates the processes required to implement the chosen candidate system. The necessary activities needed in the production-consumption cycle are explained and lead to the actual implementation of the proposed system into a production process. As this research is only a study in system feasibility, the decision to fund actual implementation must rest with the proper authorities and is beyond the scope of this research.

Conclusion

Inadequate access to the hospital appointment system is the result of several factors. The implementation of a formalized methodology is used to analyze the stated problem and provide a single "best" solution. The following review

of literature will examine the difficulties others have encountered with appointment systems.

II. Literature Review

Generally, appointment systems are an attempt to provide fair and responsive treatment to all patients. Increasing patient workloads have tested both the efficiency and effectiveness of traditional appointment systems.

Appointment Systems

When Casper Weinberger became the Secretary of Defense in 1981, he established as prime goals of the administration: the "elimination of duplication and waste" (6:Chap 13,19). This top management concern, reinforced by Congressional demands, has forced defense agencies to carefully evaluate their spending. One agency, the USAF Medical Service, manages a large and complex budget. Effective management of the Medical Service's budget, may at times require a reduction in resources, forcing managers to be efficient in as many areas as possible. Such constraints on appointment system resources, encourages development of more efficient procedures in this arena.

Contacting an appointment desk is usually a patient's first step in obtaining medical treatment (3:24). Consequently, the overall perception of a hospital may be based on the efficiency of its appointment system. For both the hospital and patients, the effects of a good appointment system will "optimize the available resources and minimize the waiting time of patients" (10:48). From a patient's

perspective, making an appointment should be relatively easy and convenient (9:65).

To achieve such perceptions an appointment system must do more than just transfer patient appointment information to respective departments and clinics. A successful appointment system will involve physician and patient punctuality, management control, and good clerical procedures (10:49).

Problems with punctuality may indicate an imbalance with a hospital's resources. In a consulting study for the U.S. Public Health Service Hospital at New Orleans LA, Dr. Edward Madden Jr., Chief of the Health Service Research Department, discovered that it is more often the physicians who are late, versus the generally assumed patient tardiness (10:49). Such imbalanced management can detract from a patient's overall perception of a facility. Franz Herpok believes that health service administrators can optimize "the relationship among the priorities of patients, providers and support personnel" through a balanced allocation of resources (personnel, funds, physical space) (9:66). Such an endeavor is particularly challenging in a military environment where three patient populations exist; active duty, dependent, and retiree.

Effective appointment systems are the result of management effort and are of great importance to multi-faceted care providers such as the military (26:392). Major

Brandler, in an article for the <u>USAF Medical Service Digest</u>, outlined many of the current problems associated with military medical care including the difficulties with the appointment system. Brandler denoted appointment calls reaching busy signals, being placed on hold, or told to call back later as a significant problem (3:26). He further went on to suggest the following possible solutions for improving access to the appointment system.

1. Information brochure explaining scheduling process and times.

2. Stagger scheduling for clinics.

3. Change staffing -- full-time to part-time, stagger hours, etc.

4. Add equipment/staff, if necessary.

5. Automated scheduling system. (3:26)

Implementation of any or all of these suggestions depends on effective staff coordination and department organization (3:29).

A successful system is based in part on organizing departments in the most efficient manner. This may include de-centralized, centralized, or a combination of both. To better understand the features of centrally organizing appointment scheduling efforts, Colonel Richard Stuart (USA), Commander of the U.S. Army Hospital at Bremerhaven, West Germany, surveyed four large US Army hospitals in 1972. From this study he drew some important conclusions that can also be applicable to de-centralized appointment systems.

One of Stuart's major findings was that the key to any good appointment system is an efficient telecommunications operation. Without adequate patient access, even the most advanced system is useless. Based on his study of military appointment systems, he recommended the following:

1. A need for adequate and dependable staffing.

2. Limit busy signals to less than six percent of all calls.

3. Appointments should be made only by telephone.

4. At least 70 percent of outpatient visits should be booked in advanced.

5. Hospitals should have separate numbers for cancellations and for long-distance calls. (26:393)

Additionally, Colonel Stuart found the average appointment call lasted between 2.1 and 2.4 minutes and information calls averaging less than 2 minutes (26:394).

Stuart's research established many standards for military hospitals to emulate. His concerns for efficient appointment systems in military medical facilities continue to the present. This is evidenced by the fact that appointment systems were the number one item on the USAF Surgeon General's Information Systems top ten problem list for fiscal year 1988 (27).

Regardless of how good an appointment system is, offering a wide range of services to a growing number of outpatients, taxes even the very best systems. An overriding factor for the success of any appointment system

will always be in terms of patient accessibility. This access is constrained by the numerous variables that exist within a matrix of operations. Through a careful methodological analysis of multiple concepts, a successful system can be developed that will satisfy the needs of the problem.

Methodology Background

Prior to the twentieth century, development of products and technologies underwent a slow, evolutionary process (1:2). During the 1930's and 1940's, the complexity of technology quickly widened the gap between the initial idea for a process and its actual utilization. Hall defined this gap as "organized creative technology" and what "shortens the gap between discoveries and their subsequent application" is what he called "system engineering" (7:3). The increased complexity as Hall and others have understood it, has brought about an increasing number of interactions between the multiple facets of manufacturing. These interactions involve many technical, scientific, and communication problems involving individuals with varying backgrounds, levels of ability, and skills (14:3). Some of the early users of systems engineering included RCA during its development of broadcast television service in the 1930's. The RAND Corporation developed the idea of systems analysis or initial research, which became the foundation for systems engineering. But it was Bell Laboratories that

was the first to use the term "system engineering" during the early 1940's (7:7).

The objectives of systems engineering, included the need to "balance the overall development program, making the best use of manpower and resources" (7:12). This efficiency would be the result of careful planning, making use of new knowledge, and providing effective communication to management for control and guidance (7:12). Understandably, system engineering was not without its drawbacks. A chief disadvantage was the use of value judgments in the objective statement, and later in defining which objectives in the design should be used first (7:11).

In 1962 Morris Asimow, published a book entitled Introduction to Design. In it, Asimow delineated a design morphology that answered the needs for system engineering in product design. He realized, as others before him had, that in today's society there is a shorter amount of time for development of increasingly complex designs which increase the risk of error or failure (1:2).

Asimow realized that like the different approaches in philosophy there were also many ways to attack a problem or set of problems with differing views. Towards this end he outlined a fourteen step process that led to the production phase of a product from its initial needs analysis. The first step in the process, dictated that the design must be in response to some need, either social or individual, that

can be met by technological design (1:5). The remaining outline further examines the need for the project in terms of physical, financial, and design constraints.

It was quickly seen that the design morphology Asimow had outlined, provided a systematic approach to careful planing of complex systems. Asimow suggested some questions to reflect on when pondering the use of such a morphology.

1. When designing a system involving thousands of attributes, which ones are really important?

2. From who's point of view should the advantage of an attribute be ascribed?

3. How much confidence can we attach to a design to be carried out to a physical product? (1:24)

The result of Asimow's work was an orderly sequence of decisions, which when resolved emerged with an effective answer to the needs identified (14:3).

While the work of both Hall and Asimow helped the development of large scale planning projects, no effort was made to collectively assemble together the various philosophies required for such efforts. Thus the need for a sequential course in design, planning, and decision making was born.

Recognizing this need, resulted in a collaboration effort, over the years, between Benjamin Ostrofsky and his colleagues. The results of their work were based largely on Asimow's early work but organized into a less technical and more manageable methodology for instructional purposes.

Combining both old and new concepts, Ostrofsky and others allowed managers, designers and students as well to:

> relate logically, some for the first time, the requirements of their activity and to decide for themselves the level to which their knowledge and resources would engender confidence in their conclusions. (14:x)

The result of his work gave the user a better comprehension of real world problem needs, decisions required to overcome them, and the risks associated with such decisions. Perhaps the most endearing feature of Ostrofsky's methodology is that it allows a student to accomplish the procedures with his own abilities, giving him confidence and success with its features. It is important to point out, though, that adhering to the design morphology itself does not guarantee a successful solution. Making such a claim would propose that "any problem can be successfully solved, or any system successfully designed, if one were only to follow the logic of the morphology" (14:4). The methodology, therefore, is not so much a problem solver but rather a structured problem analyzer.

Conclusion

The struggle with appointment systems has grown through the years with increasing patient populations. Appointment systems for military medical facilities are particularly challenging, because they have a complex diversity of patients. Studies have been accomplished that

point to the need for a more efficient and effective appointment system.

To accomplish a sufficient study, a systematic approach is needed to analyze the problem. Early work by Arthur Hall and Morris Asimow, delineated an exhaustive and detailed approach to the planning, design, and development of complex engineering problems. Benjamin Ostrofsky expanded on these concepts to provide a design methodology teachable at the university level. The chapters that follow are the results of implementing his methodology and examining the appointment system accessibility problem and its needs.

III. Feasibility Study

Having established a definitive problem of accessing the appointment system, this chapter is devoted to developing 'a set of useful solutions to meet the needs' of that problem (14:29). The result is a set of possible solutions or candidate systems, that satisfy the problem.

Needs Analysis

Having defined the specific problem earlier in Chapter 1, a needs analysis provides the justification for additional expense and effort (14:31). This analysis can be done in a variety of ways. Ostrofsky advocates the use of surveys, suggesting

> considerable insight can be gained concerning the characteristics associated with the consumer's or operator's ideas about the nature of the problem needs. (14:33)

After consulting with Major Shields, it was agreed that a survey would be more beneficial if administered to staff members who routinely work with the appointment system or rely on its information. Furthermore the survey was restricted to the seven departments that utilize the current automated appointment system (22).

The resulting population consisted of ten officers in executive management; seven hospital department chairmen; and eleven appointment clerks and their seven respective supervisors, for a total of 34 individuals (35 positions

were identified but one officer in executive management also served as a department chairman). The questionnaire itself is contained in Appendix A. A stratified tabulation of results can be found in Appendix B.

Questionnaire results. The questionnaire suggested a generally satisfied feeling with the present appointment system but indicated improvements could be made. For example, in response to question six illustrated in Table 1, 30 percent of the population was either dissatisfied or very dissatisfied with the appointment system overall. Satisfaction with the appointment system accounted for 44 percent of the staff with just 3 percent being very satisfied. The remaining 23 percent were neither satisfied nor dissatisfied or the question was not applicable to them based on their job description.

Table 1. Tabulated Responses to Question Six

6. What is your overall opinion of the appointment system used to make appointments?	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management	33%	11%	22%	0%	33%	0%
Department Chair	0%	0%	43%	43%	14%	0%
Subtotal	19%	6%	31%	19%	25%	0%
Supervisor	0%	0%	29%	14%	57%	0%
Appointment Clerk	0%	9%	9%	9%	64%	9%
Subtotal	0%	6%	17%	11%	61%	6%
COMBINED TOTAL	9%	6%	24%	15%	44%	3%

A second example summarized in Table 2, showed 24 percent of the population being very dissatisfied and 21 percent being dissatisfied with question five, pertaining to the number of appointment scheduling people in each clinic. Alternatively, 26 percent were satisfied and 12 percent were very satisfied, resulting in a divided opinion on the question. The remaining 17 percent were neither satisfied nor dissatisfied or the question was not applicable to them based on their job description.

Table 2. Tabulated Responses to Question Five

5. How satisfied are you with the number of appointment scheduling people in your area?	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management	44%	33%	0%	11%	11%	0%
Department Chair	0%	29%	71%	0%	0%	0%
Subtotal	25%	31%	31%	6%	6%	0%
Supervisor	0%	14%	14%	14%	43%	14%
Appointment Clerk	0%	18%	9%	0%	45%	27%
Subtotal	0%	17%	11%	6%	44%	22%
COMBINED TOTAL	12%	24%	21%	6%	26%	12%

The three remaining questions were not addressed as they are more applicable to further study on the appointment system other than accessibility problems.

Justification for further analysis was identified in a talking paper, prepared by Major Shields in July 1989 (24). It was a compilation of standards for USAF Medical Center

appointment systems. The standards listed were derived from both local and DOD recommendations.

Project goals. As a study progresses it is sometimes easy to lose sight of the original needs. Ostrofsky suggests preparing a statement of goals to provide the designer with a measurement of success (14:33). The following goals were obtained from information contained in the needs analysis and the talking paper (24).

1. Time on hold should be limited to less than 5 minutes.

2. Avoid requiring appointments be made at either the start or end of each month. This can result in a smoother workload distribution.

3. Less than six percent of all calls should encounter a busy signal.

4. Downtime should be limited to only three percent of total monthly hours available.

5. At least 70 percent of appointments should be made before the patient arrives, thereby smoothing workload distributions.

6. Walk-in rates should be limited to 10 percent of patient visits, again smoothing workloads.

7. Average appointment transactions should last less than 2.5 minutes.

8. Calls for information should not exceed 10 percent of all calls received.

9. One appointment clerk should be available for every 2,000 monthly calls.

10. An average of 1.5 telephone lines should be available for every appointment clerk.

Identification and Formulation of the Problem

The purpose of this stage in the methodology "is to bound the needs or requirements subjectively" (14:35). In doing so a realistic picture or concept of the problem is defined that allows a better grasp of the problem. To do this, the production/consumption cycle is examined step by step in an attempt to identify as many characterizing attributes as possible. For each phase in the life cycle, consideration is given to what is input and what results as output.

Desired outputs from each phase may not always be achievable but in effect serve as goals to strive for. Undesired output, on the other hand, enumerates the unwanted aspects of the phase which hopefully can be eliminated or at the very least minimized.

The input side of a phase is divided into what is intended and what is subject to the environment. Intended inputs include items or processes necessary to start the particular process. Environmental inputs, describe what already exists in our system that will effect this phase in the life cycle.

To define these boundaries one must be aware of how an organization's goals and available resources may affect the project. Essentially, they establish the outer framework within which a product or service's life cycle occurs. According to Ostrofsky, a product encounters four phases

during its life-cycle: production, distribution, consumption/operation, and retirement (14:8). These phases are described in general and also how they relate to appointment systems.

Production Phase. Initially, the transformation of raw materials into finished goods is accomplished during the Production phase. Other processes may occur during this phase which can contribute to a product's future success.

For this study, the product was defined as an available medical appointment from any of the clinics utilizing the centralized appointment system. The product is transformed from the raw materials or intended inputs into an available patient appointment. Table 3 is an outline analysis of the Production phase.

Table 3. Production Activity Analysis

INPUTS	
Intended	**Environmental**
1. Provider's schedule	1. Type of appt system
2. Computer online	2. Method of appointment booking
3. Appt books available	
OUTPUTS	
Desired	**Undesired**
1. All providers available	1. Limited providers
2. Maximum number of slots available	2. Incomplete or missing medical records
3. No prior conflicting commitments	3. Limited number of technicians for asst
4. Four week block of appts for scheduling	4. Reduced availability of appointments

While the general output is an appointment, its' success in the Distribution phase is contingent upon the output features.

Distribution Phase. According to Ostrofsky, this phase "accomplishes the phase-in of the product or process to the ultimate operators or consumers" (14:11). Before a product reaches the intended recipients it may undergo a variety of distribution activities.

The distribution phase, outlined in Table 4, involves the matching of eligible patients with the most convenient appointment slots.

Table 4. Distribution Activity Analysis

INPUTS	
Intended	Environmental
1. Equal daily and weekly distribution of calls	1. Scheduling system
2. Available patient info	2. Screen or appointment book layout
3. High MTBF for hardware and software	3. Number of telephone lines available
4. Low MTTR for hardware	4. MTBF for telephone system
5. Undistracted clerks	5. Length of time slots
6. Pleasant work environment	
7. No calls for information	
8. No busy signals	
9. An available appointment	
OUTPUTS	
Desired	Undesired
1. Minimizing the length of time on hold	1. Unable to find a suitable appointment time
2. Favorable appt slot located for patient	2. Leaving someone on hold longer than 5 minutes
3. Courteous clerks	3. Difficulty in verifying patient eligibility
4. Availability to answer phones	4. Missing medical records

This can involve matching patients with specifically requested providers.

Consumption/Operation Phase. Once a consumer has the product or service, it is then consumed or operated in a manner for which it was produced. Consumer satisfaction with a product is crucial as it forms the basis for continued or modified production of the product.

The Consumption/Operation phase identified in Table 5, entails the patient who arrives for their scheduled appointment and meets with the provider. Alternatively this can also involve the patient who is unable to meet their appointment time and must either cancel or reschedule.

Table 5. Consumption/Operation Activity Analysis

INPUTS	
Intended	**Environmental**
1. Provider present for appointment time	1. Inclement Weather
2. Provider on schedule	2. Private matters
3. Patient present	3. Mobility exercises
	4. Parking available
	5. Location of clinic
OUTPUTS	
Desired	**Undesired**
1. Patient arrives prior to scheduled appointment	1. Patient is late
2. Patient uses allotted slot of time	2. Patient fails to show for appointment
	3. Patient fails to cancel or change an appointment

In either case the appointment becomes an available product and can be recycled back to the distribution stage if

sufficient time exists, otherwise it is forwarded to the Retirement stage.

Retirement Phase. Often overlooked is the eventual need for product retirement. Unlike services, products may become technically obsolete in a few years, or wear out and become unrepairable. Also, thought must be given to the eventual demise or possible future service that can be derived from a product. Such extended use may occur through the recycling of materials or retooling of worn parts.

The final phase in a product's life, is the planned activity which removes it from the life cycle. Table 6 outlines the retirement of an appointment, which usually occurs after the patient has met with the provider.

Table 6. Retirement Activity Analysis

INPUT	
Intended 1. Send back to distribution stage if possible 2. Substitute walk-in patient for a no-show	Environmental 1. Provider is made unavailable by unexpected mission requirements
OUTPUTS	
Desired 1. Patient is seen and treated	Undesired 1. Patent reschedules another appointment 2. Appointment is left unfilled

Synthesis of Solutions

This is the third step in the feasibility study and involves "the piecing together of activities to integrate the needs established and defined boundaries" (14:54). The sequence of events, portrayed in the product/consumption cycle provides a flow of functions which help meet the needs of the cycle, as illustrated in Figure 1. As mentioned earlier, only a portion of the entire cycle will be considered for solution as illustrated in Figure 2. That portion was identified by the needs analysis as a more efficient access method to the Medical Center appointment system.

Although an inclusive listing of concepts may include some highly questionable approaches, eliminating any concept before it's been evaluated increases the risk of discarding the optimal candidate system itself. As a result, all of the following concepts meet the identified need, but careful analysis is required to extract the best one overall.

1. Utilize a system with manual appointment booking and standard telephonic access.

2. Utilize a system with automated appointment booking and standard telephonic access.

3. Utilize a system with both automated appointment booking and computerized telephonic access.

To maximize the potential solutions to the problem the concepts must be "broken down into their corresponding subsystems functions and activities" (14:257). Each subsystem is a part that contributes to the overall function

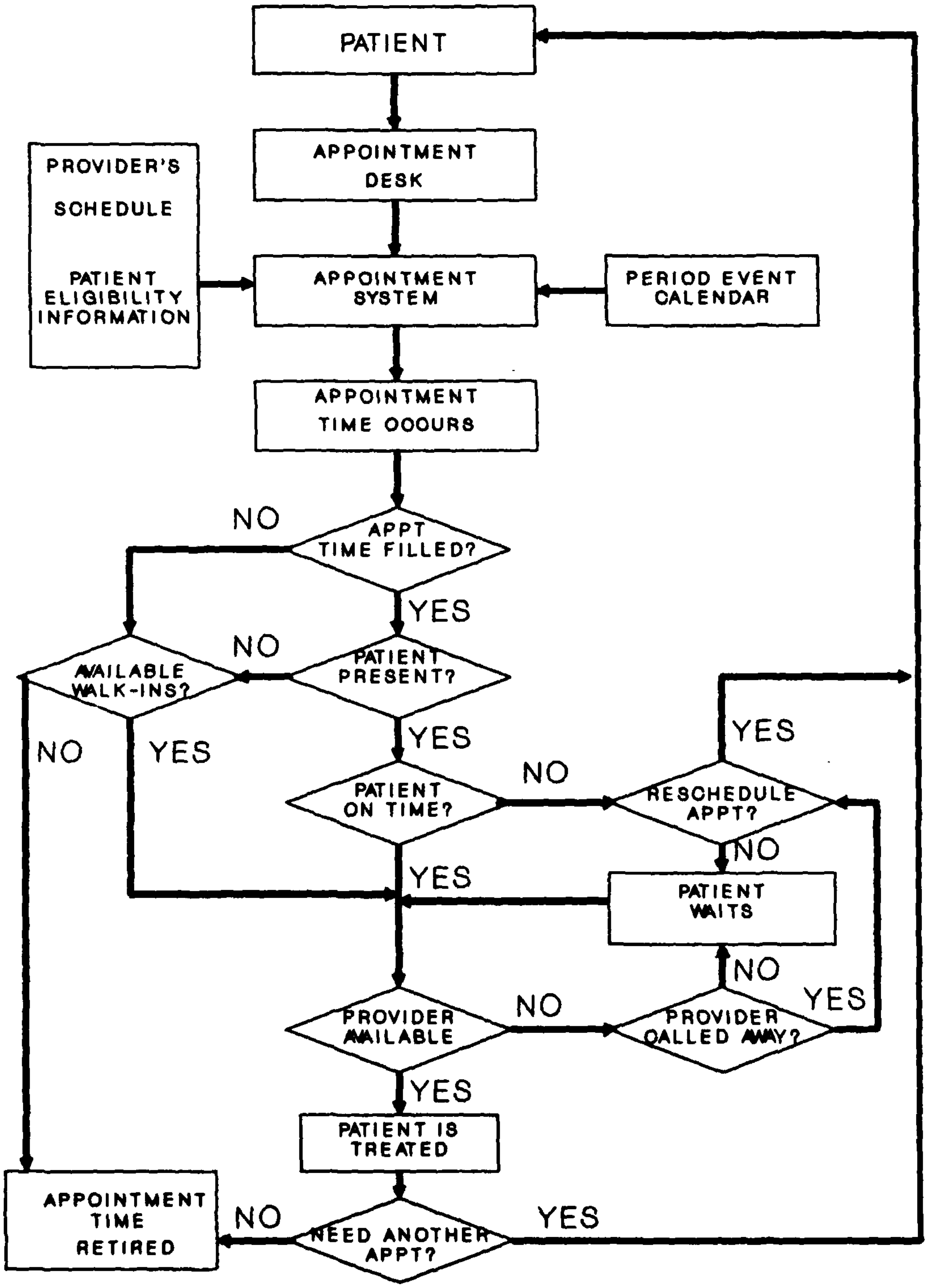


Figure 1. Appointment System Activity Life-Cycle

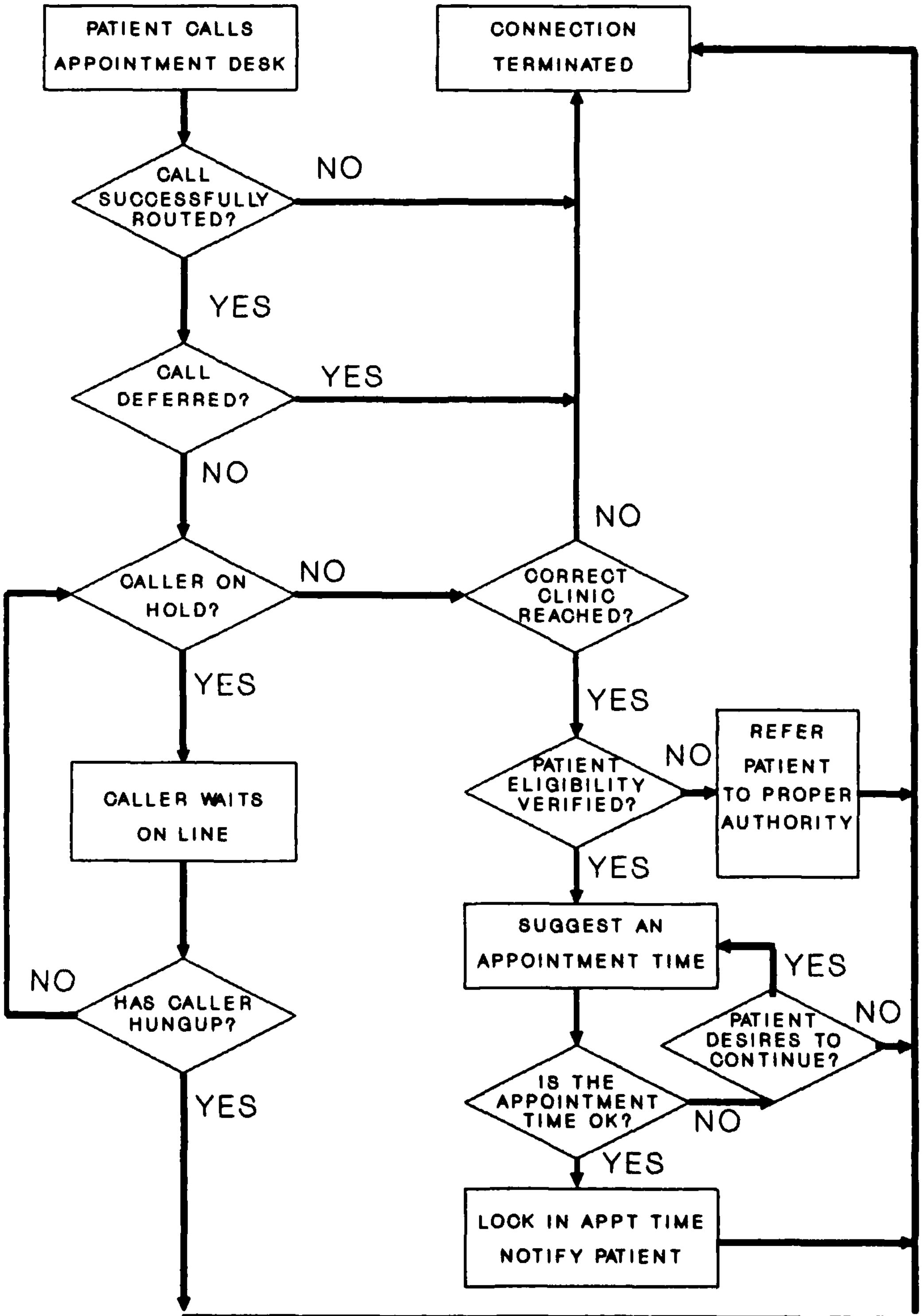


Figure 2. Appointment Booking Process

of the system. It is composed of many activities or alternatives, each of which contributes to the completion of an appointment call.

Candidate systems are created by combining one subsystem activity or alternative from each subsystem function. This results in many possibilities, but is an attempt to capture the optimal candidate system.

Three concepts, whi h provide patients with access to the Medical Center appointment system, have been derived. Figure 3 illustrates the first concept which relies on the traditional manual bookkeeping method of making appointments. This requires the patient to either call for an appointment or make the appointment in person. The second approach, illustrated in Figure 4, reflects the current Medical Center appointment system. Computerized appointment books are accessed to enter a patient into the appointment system. In Figure 5, the final concept incorporates computerized telephone automation to actually answer the phone calls. Such a device could complete some of the calls while others would have to be deferred to an actual appointment clerk.

Although all three concepts are potentially capable of satisfying the objectives, Concept I relies on a labor intensive methodology. Since the original objective was to become more efficient, such a concept can no longer be considered viable in light of the following information.

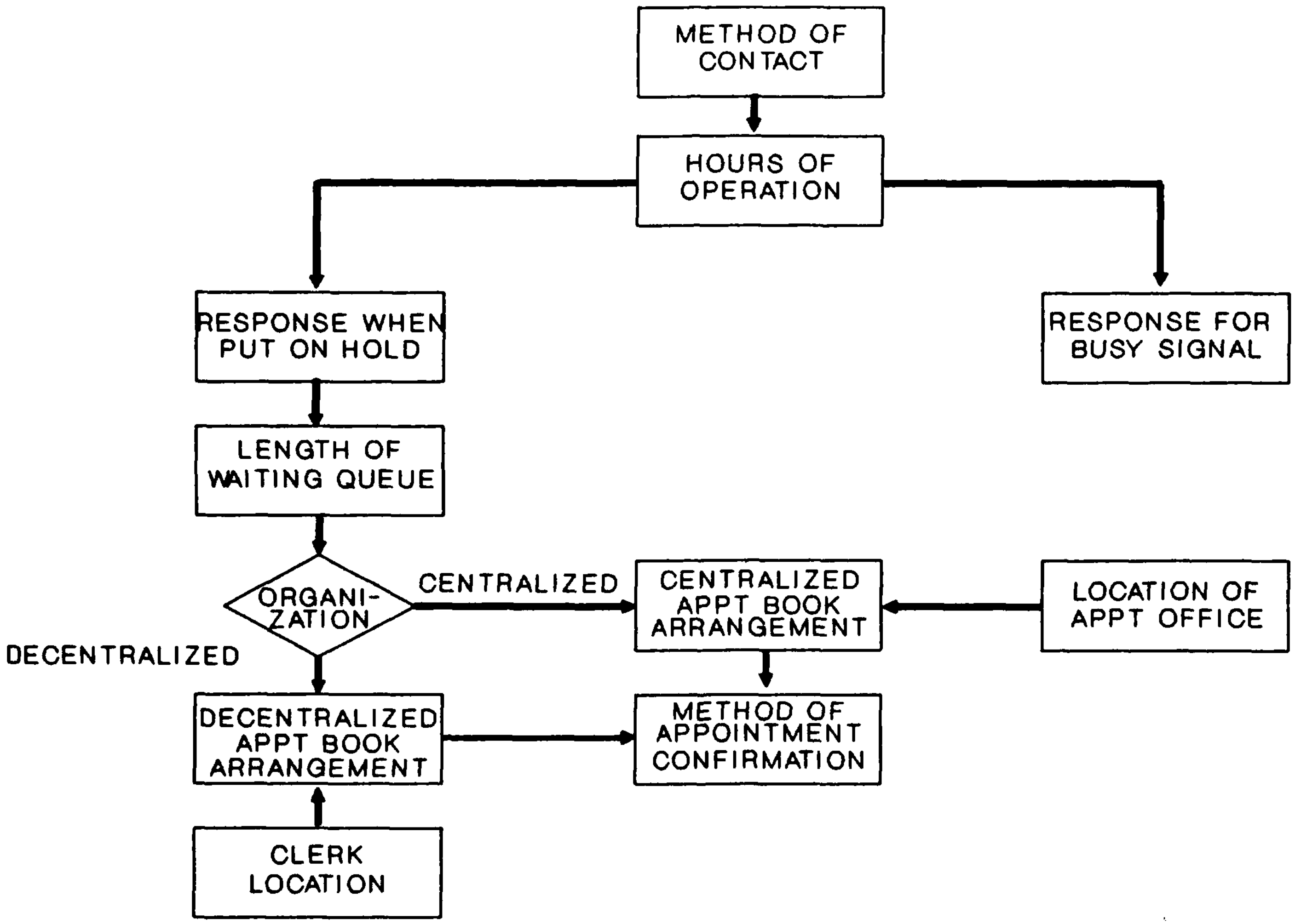


Figure 3. CONCEPT I: Manual Appointment Booking with Standard Telephonic Access

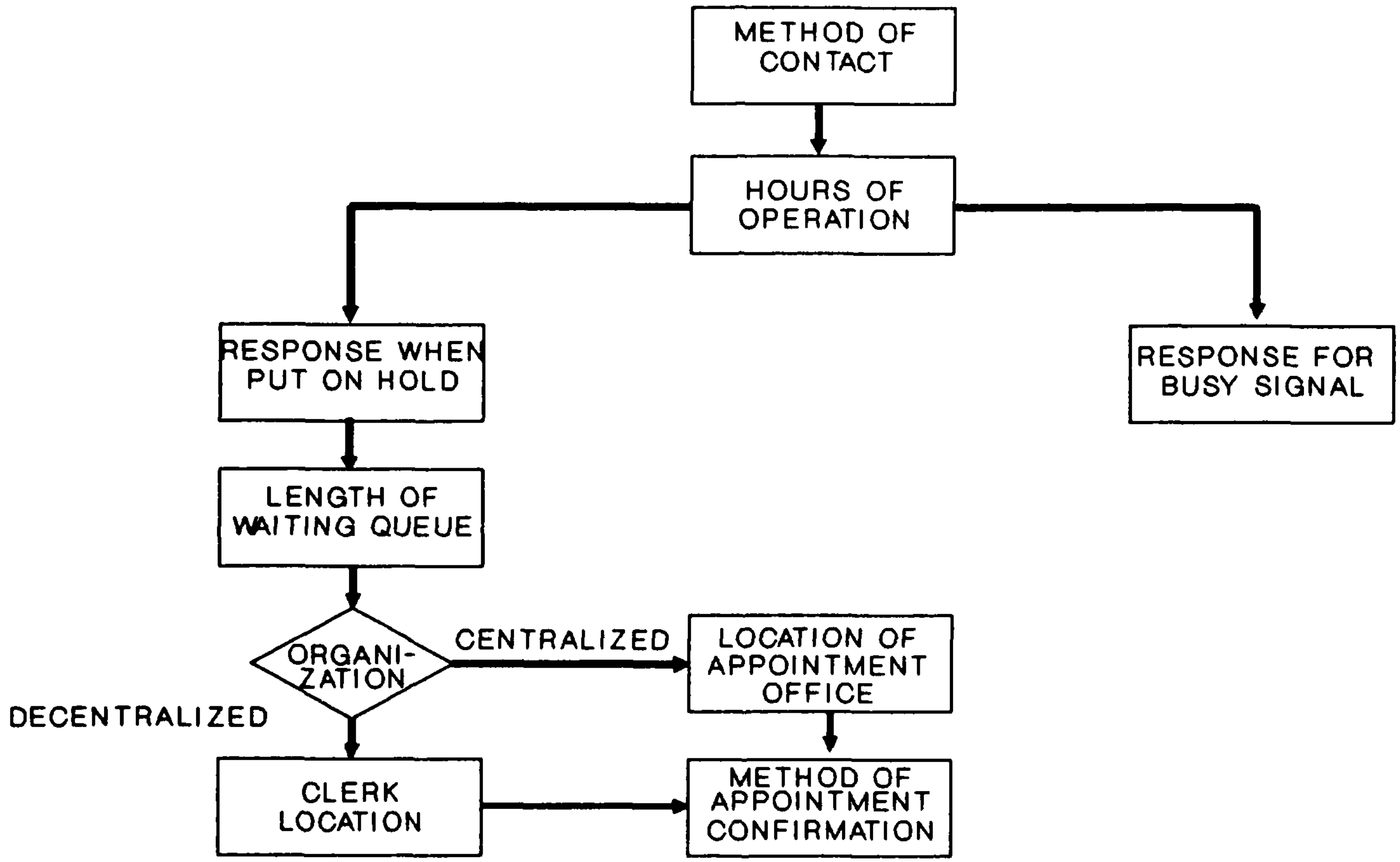


Figure 4. CONCEPT II: Automated Appointment Booking with Standard Telephonic Access

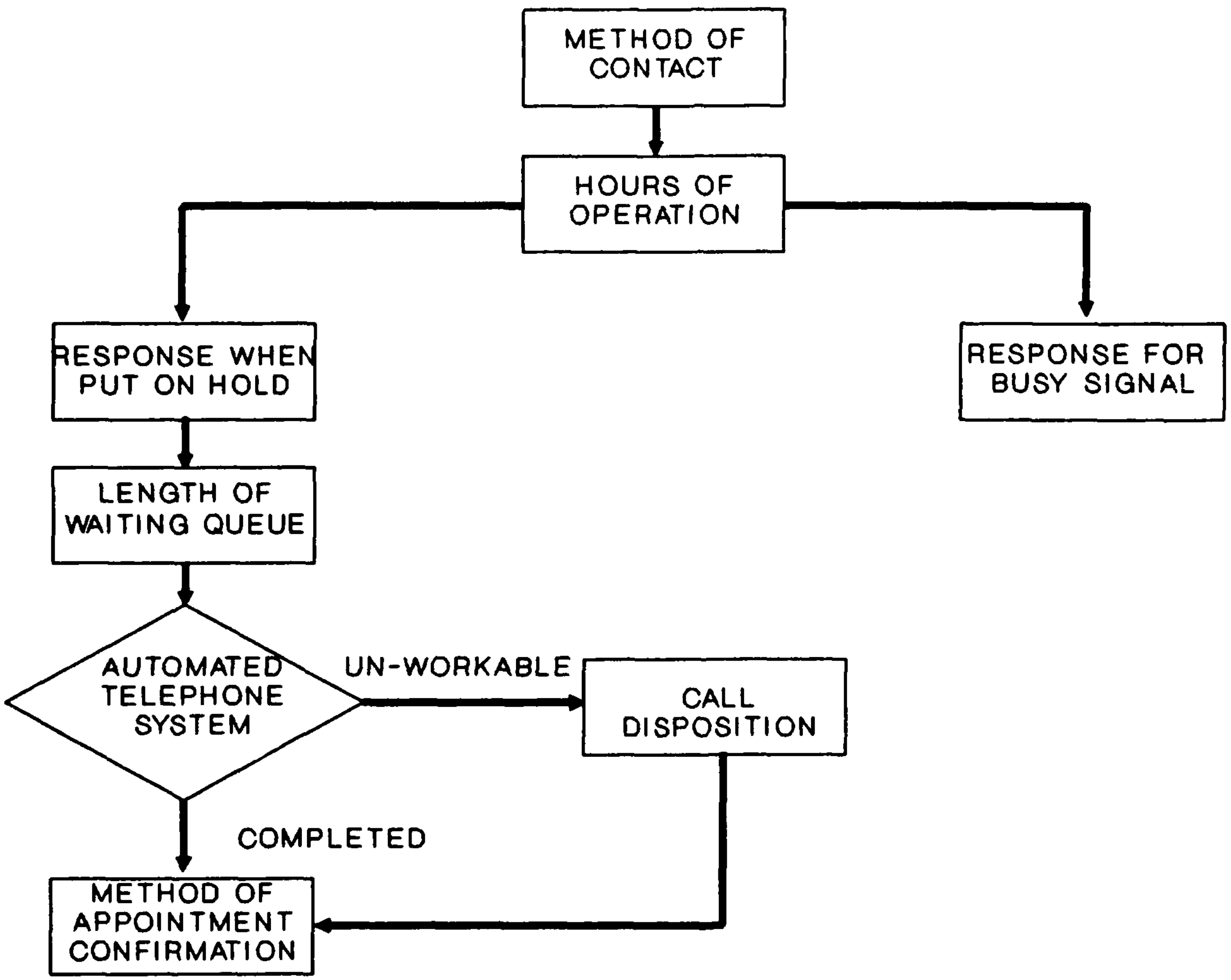


Figure 5. CONCEPT III: Automated Appointment Booking with Computerized Telephonic Access

During fiscal year 1988, the Medical Center saw more than 363,000 clinical outpatient visits. This excludes the more than 28,000 inpatient visits, 33,000 emergency room visits, and 26,000 Mental Health appointments (22). Such a work load would result in eleven appointment clerks having to manually book an average 16.77 appointments per hour. This average fails to account for peak workload periods and does not meet the goals previously stated. Hence Concept I was removed from any further consideration and attention was focused on Concepts II and III.

A breakdown of each concept's subsystems and accompanying alternatives are listed below. Concept II is illustrated in Table 7. Combinations of each of the alternatives resulted in the following number of candidate systems:

A		B		C		D		E		F		G		H		I		
2	x	3	x	2	x	7	x	6	x	2	x	4	x	2	x	7	=	56,448 candidate systems

Table 7. Concept II Candidate Systems

A. Method of Contact

1. Telephone
2. In person

B. Hours of Operation

1. One 8 hour shift
2. One 8 and one 4 hour shift
3. Two 8 hour shifts

C. Response for Deferred Calls

1. Industry standard busy signal
2. Informational response

Table 7 continued.

D. Response when Put on Hold

1. Music
2. Which clinic reached
3. Status in queue
4. Combine 1 and 2
5. Combine 2 and 3
6. Combine 1 and 3
7. Combine 1, 2 and 3

E. Length of Waiting Queue

1. 0 callers
2. 1 callers
3. 2 callers
4. 3 callers
5. 4 callers
6. 5 callers

F. Departmental Organization

1. Centralized
2. Decentralized

G. Location of Appointment Office

1. On site
   a. Single Room
   b. Multiple Rooms
2. Off Site
   a. Single Room
   b. Multiple Rooms

H. Clerk Location

1. Within Clinic
2. Outside clinic

I. Method of Appointment Confirmation

1. Verbal reply
2. Written response
   a. USPS 1st class letter
   b. Base distribution (BITS)
   c. FAX transmission
   d. Express Mail
   e. Electronic Mail
   f. Personally delivered

Concept III is outlined in Table 8. Combinations of each of the alternatives resulted in the following candidate systems:

A		B		C		D		E		F		G		H		
2	x	3	x	2	x	7	x	6	x	7	x	6	x	7	=	148,176 candidate systems

Table 8. Concept III Candidate Systems

A. Method of Contact

1. Telephone
2. In person

B. Hours of Operation

1. One 8 hour shift
2. One 8 and one 4 hour shift
3. Two 8 hour shifts

C. Response for Deferred Calls

1. Industry standard busy signal
2. Informational response

D. Response when Put on Hold

1. Music
2. Which clinic reached
3. Status in queue
4. Combine 1 and 2
5. Combine 2 and 3
6. Combine 1 and 3
7. Combine 1, 2, and 3

E. Length of Waiting Queue

1. 0 callers
2. 1 callers
3. 2 callers
4. 3 callers
5. 4 callers
6. 5 callers

Table 8 continued.

	F. Automation Attendant
1.	Prioritize calls (i.e. Information, acute care need, routine appt)
2.	Provide information
3.	Schedule routine appts
4.	Combine 1 and 2
5.	Combine 1 and 3
6.	Combine 2 and 3
7.	Combine 1, 2 and 3
	G. Call Disposition
1.	Manual Intervention for patient assistance
2.	Rotary dial phone default
3.	Acute care need
4.	Combine 1 and 2
5.	Combine 2 and 3
6.	Combine 1 and 3
7.	Combine 1, 2 and 3
	H. Method of Appointment Confirmation
1.	Verbal reply
2.	Written response
	a. USPS 1st class letter
	b. Base distribution (BITS)
	c. FAX transmission
	d. Express Mail
	e. Electronic Mail
	f. Personally delivered

Having created an exhaustive list of candidate systems, the focus moved to eliminating those which were clearly infeasible for physical, economic, or financial reasons.

Screening of Candidate Systems

In the attempt to include the optimal candidate system no candidates should be eliminated unless proven to be physically infeasible to operate or produce as depicted in

Figure 6. Consideration should also be given towards the constraints and bounds established during the input-output analysis.

Physical Realizability. With components of the subsystem being developed separately from each other it becomes necessary to eliminate those combinations which are not physically compatible. The combinations listed below in Tables 9 and 10 for both concepts were removed from consideration.

Table 9. Concept II Physical Incompatibilities

Component	Incompatible With
A2	C1,C2,D1-6,E1-6
F1	H1,H2
F2	G1a,G1b,G2a,G2b
Net Candidate systems available: 56,448 - 90 = 56,358	

Table 10. Concept III Physical Incompatibilities

Component	Incompatible With
A2	C1,C2,D1-6,E1-6,F1-6,G2-6
Net Candidate systems available: 148,176 - 3528 = 144,648	

Economic Worthwhileness. Any candidate system under review must be able to provide an acceptable level of return on the investment made on it. That is, "the total resources required to complete the design of the candidate must be less than the value received from its completion" (14:58).

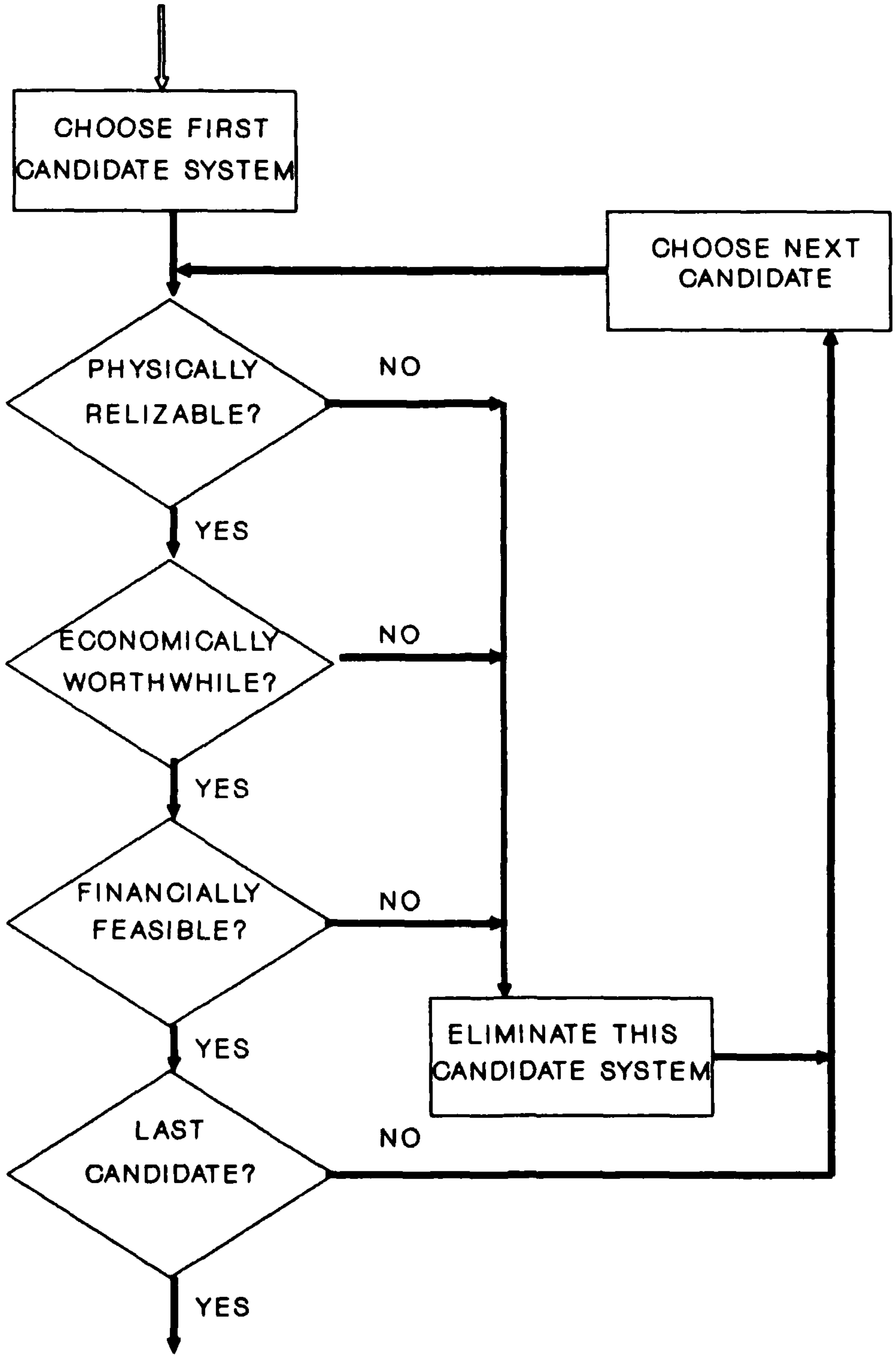


Figure 6. Screening of Candidate Systems (14:56)

Unlike manufactured products, productivity from services is difficult to measure. The absence of a profit motivated unit of output excludes traditional economic measurements of price-volume relationship, break even analysis, and cost estimates. Although appointment quality was mentioned earlier in the Desired Output portion of the Production phase, such output "with reference to quality ... is even more ephemeral in services than in manufacturing" (16:53).

Most activities under both concepts were considered economically worthwhile to develop. The only exception was the activity entitled "Method of Appointment Confirmation". For both concepts the candidates in Tables 11 and 12 were excluded from further consideration.

Table 11. Concept II Economic Impracticalities

Component	Incompatible With
I2c	A1-2,B1-3,C1-2,D1-7, E1-6,F1-2,G1a-2b,H1-2
I2d	A1-2,B1-3,C1-2,D1-7, E1-6,F1-2,G1a-2b,H1-2
Net candidate systems available:	56,358 - 16,128 = 40,230

Justification for the exclusion of candidates I2c and H2c, Facsimile transmissions, is found in the definition of use. A FAX is designed to provide a timely transmission of important documents when nothing else is available. This precludes its use from anything but time-sensitive

Table 12. Concept III Economic Impracticalities

Component	Incompatible With
H2c	A1-2,B1-3,C1-2,D1-7, E1-6,F1-7,G1-7
H2d	A1-2,B1-3,C1-2,D1-7, E1-6,F1-7,G1-7
Net candidate systems available:	148,648 - 49,392 = 99,256

documents. Other drawbacks include the need for both parties to either own or have access to a FAX and any long distance charges must be included in cost estimates.

Components I2d and H2d, Express Mail service, is cost prohibitive at $7.00 to $9.00 a letter. The matter of urgency that FAX transmission and Express Mail solve should not exist in an appointment environment whose purpose is to plan ahead.

Financial Feasibility. Even though a candidate system can be shown to be an optimal solution, a lack of financial resources can eliminate such a project from further development. Consideration should be given to the nature of the systems and the areas of funding.

Tight budget constraints have made many DOD projects extremely limited in scope. Even so, development of any one of the candidate systems could be within funding requirements for base level contract administration. Medical information systems local purchase levels presently justify purchases less than $15,000 (22). Naturally, implementation

would be contingent upon the availability of funds and willingness to develop the system.

Conclusions and Summary

The need for more efficient access to the appointment system has been documented. A review of literature has shown the need for and significance of an appointment system. This was followed by a discussion on the developmental history of the methodology used in this research.

Within the framework of the organization, input-output boundaries were established to define the limitations and expectations of an appointment during its normal life cycle. This study then focused on one part of the life cycle, that of efficient access to the distribution phase.

Utilizing standards set forth by the USAF and the DOD, established goals were defined to achieve efficient appointment access. To solve the identified need, three solutions or concepts were developed. Only Concepts II and III were selected for further analysis to maintain the original goal of efficiency in the system.

Activities were identified for the concepts and broken out into subsystems, from which candidate systems would be derived. With several thousand candidate systems possible, an initial attempt was made to discard candidate systems

that were considered physically, economically, or financially infeasible to develop further.

Having identified the problem and established a set of possible solutions, the next concern was to select a single "best" candidate system. The remaining methodology, set forth in Chapter 4, establishes one system that "best" meets the needs set forth in Chapter 1.

IV. Preliminary Activities

The purpose of the previous chapter was to establish the concepts that would meet the identified needs. This resulted in the creation of many candidate systems. With this information, the goal of the "Preliminary Activities" section is to find the "best" solution or as Ostrofsky wrote, "identify the optimal candidate system from the set of candidates already defined" (14:69).

Preparation for Analysis

Despite efforts to eliminate candidate systems for physical or economic reasons in Chapter III, many thousand remain. The more candidate systems the more difficult it becomes to subjectively evaluate them, but the better the chance of finding the "best" solution.

To gain a new perspective on the candidates, this activity "provides an insight into the set of candidates and their relationship to each other and to the needs analysis" (14:74). Such an analysis results in the following objectives.

1. An increasing awareness of the nature of the criteria to be met by the emerging system.

2. An increasing knowledge of the nature of the candidate systems for a given concept and the qualities of each concept in the broad domain of possible concepts available to meet the needs defined. (14:74)

To accomplish the above objectives, Ostrofsky suggests grouping candidate systems together based on similar characteristics. This provides renewed consideration of existing criteria. The adequacy of each of the groups is identified in Tables 13 and 14, by preparing a list of advantages and disadvantages associated with each grouping. The areas addressed in these tables are established to demonstrate the pros and cons of these systems and how they interact with the optimization process. Further discussion of these areas follows and is eventually quantified.

Definition of Criteria

To evaluate the performance of a candidate system, some scale must be developed to measure it against. A set of criteria can be developed to quantitatively choose the best candidate system. Criteria can be measurable quantities such as time or dollars, or exist in a more abstract realm such as satisfaction or experience. Ostrofsky suggests extracting criteria from information in the needs analysis and listed outputs, both desired and undesired, from the input/output matrices. The clarity and precision of chosen criteria are essential for all decision elements to be adequately considered. Ostrofsky presents the following criterion development theorem:

> Any criterion not considered will not be included in the choice of the optimal candidate. (14:80)

Table 13. Concept II Grouped Candidates by Attributes

Type of Candidate	
	Advantages (26:392)
Centralized Appointment System	1. One source of information for patients. 2. Availability of dedicated staff to answer telephones. 3. Patients can make multiple clinic appointments from one call. 4. Compiles workload data for each clinic served. 5. Standardized collection of patient appointment information. 6. More precise, coordinated scheduling of all clinics served.
	Disadvantages (23:96)
	1. Lack of flexibility to handle acute care and emergency situations. 2. Increased communications between clinics and appointment area. 3. More complex system to provide training on. 4. Lack of familiarity with unique clinic needs to properly screen patients.
	Advantages (23:98)
Decentralized Appointment System	1. Greater flexibility in scheduling with. 2. Greater control by supervisors over clinic operations. 3. Easier to make follow-up and same day appointments. 4. Reduce training time for appointment clerks. 5. May appear to patient to be more responsive to needs. 6. Increased ability to prioritize patient appointment needs.
	Disadvantages (23:100)
	1. Lack of adequate coverage when appointment clerks are absent. 2. Separate telephone numbers for each clinic make it more difficult for patient access. 3. Difficulties in referring patients to other clinics. 4. Fluctuating appointment clerk productivity. 5. Increased hardware needs.

Table 14. Concept III Grouped Candidates by Attributes

Type of Candidate	
	Advantages
Telephone	1. Saves time for patient, convenience. 2. Reduces traffic and parking problems.
	Disadvantages
	1. Connection can be difficult to understand. 2. Long distance calls for some patients. 3. Telephone numbers can be lost or forgotten.
	Advantages
In-person	1. More personal attention. 2. Written confirmation acquired when done.
	Disadvantages
	1. May require larger floor space. 2. Longer to book an appointment (23:100). 3. Long lines irritate or disperse patients.
	Advantages
Automated Telephone System	1. Minimal maintenance and upkeep costs. 2. Faster and more efficient. 3. Perform several different functions. 4. Continuous operation possible.
	Disadvantages
	1. Breakdowns may shutdown entire system. 2. Automated equipment may be offensive or frustrating to some patients. 3. Programming errors may result in scheduling nightmares.
	Advantages
Manual Telephone System	1. Better able to handle emergencies. 2. Responsive and sympathetic to patient. 3. Better able to respond to questions.
	Disadvantages
	1. Absenteeism and scheduling of leave. 2. Wage raises (union contracts). 3. Morale problems.

Thus it becomes crucial to painstakingly identify those elements which are criterion, otherwise they can not be considered in the optimal system choice.

The following criteria were chosen after evaluating their ability to effectively meet the original requirements indicated in the Feasibility Study.

Response Time. Response time refers to the amount of time a call must wait before being answered. The length of time is dependant on the number of calls already in the waiting queue and the duration of these calls. It is affected indirectly by the time of day and week a call is made. In an interview with Major Donald Shields, he indicated response time to be a very important facet in achieving patient satisfaction. Minimizing this waiting time is necessary to achieve a more optimal solution.

Prioritizing. Prioritizing is a systematic approach to ranking calls based on urgency of need. Prioritizing calls is a very subjective practice and may be frustrating to a caller who is incorrectly placed in the wrong queue. Any system developed would rely on either the caller or the receiver prioritizing the call based on a set of decision rules. A successfully prioritized call will be delivered to the proper queue to be answered in turn.

Costs. Costs refers to the monetary expenditures required to compensate employees, and vendors of hardware and software. Budgetary constraints require a careful

evaluation of present and future costs when reviewing the performance of any new or current system.

User Friendliness. User friendliness is the degree to which a user, such as the appointment clerk, feels comfortable using a system. The more at ease a clerk is with a system, the fewer errors should be committed and the more responsive they are to customer needs. User friendliness is dependant upon the complexity of the system, the availability of helpful features, and the amount of training received.

System Availability. System availability is the operable presence of all needed system components when they are requested by the user (25:461). Possible component failures or system crashes must be planned for by ensuring adequate backup procedures are available. Consideration must be given to adequate repair and replacement times.

Criteria Relative Importance

Having more than one criterion, it becomes important to consider the relative weight for each. The criteria described may not be of equal importance. To distinguish the differences requires weighted values be assigned to each criteria.

These rating values, summarized in Table 15 and referred henceforth as a'(i), may be derived from any information acquired, or according to Ostrofsky, "even an intuitive evaluation of the a'(i) will usually yield a

choice closer to the optimum than assuming equal importance among criteria" (14:84). To weight the criteria, individuals involved with the appointment system at the Medical Center and individuals familiar with information systems were solicited for their candid ranking of the five criteria. The following heuristic was used to obtain a weighted set of a(i) values for each criterion.

1. Rate each criterion on a scale from 0 to 10 (with 10 indicating the most importance).

2. Normalize each rating by the total of all values.

3. Summation of a(i) for all values equals 1.0.

4. All a(i) values must range from 0 to 1.0, inclusive. (14:83)

Table 15. Criteria and Relative Weights

Criterion, x(i)		Rating, a'(i)	Weight a(i)
x1:	Response Time	9	a1: 0.24
x2:	Prioritizing	7	a2: 0.19
x3:	Cost	6	a3: 0.16
x4:	User Friendliness	8	a4: 0.22
x5:	System Availability	7	a5: 0.19
			1.00

Definition of Parameters

Having defined the criteria, it became necessary to establish measurable elements, or parameters for each criterion. Collectively, these elements assist in providing "the major, direct source of the candidate systems quantitative evaluation by the criterion" (14:86). Although some criteria can be directly measured, the more abstract

ones require the identification of submodels with elements that can be measured and used to evaluate the candidate system. Design or planning parameters are not easily quantifiable. The relationships between criteria must be understood in order to obtain the most realistic and measurable criterion elements. Ostrofsky points out that in the development process some elements may not be measurable from "current resources but which are considered as contributors to the meaning of the criterion" (14:88). When this occurs, consideration must be given to the importance of the element. If crucial, those elements must be considered by some manner so as to adequately judge the candidate system performance. Figure 7 provides an illustration of the relationship between parameters, submodels, and other criterion elements.

In Table 16, each criterion and associated element or parameter is listed. Assigned to each element is an alphabetic letter code which describes a specific design parameter outlined in Table 17. Collectively these codes were used to group and quantify each criterion.

Having completely listed the criterion elements, Ostrofsky encourages the planner to inspect them for "consistency and completeness" (14:90). In doing so, similar meanings and redundancies can be eliminated resulting in a minimal number of elements necessary to describe the criteria. It is equally important to be as

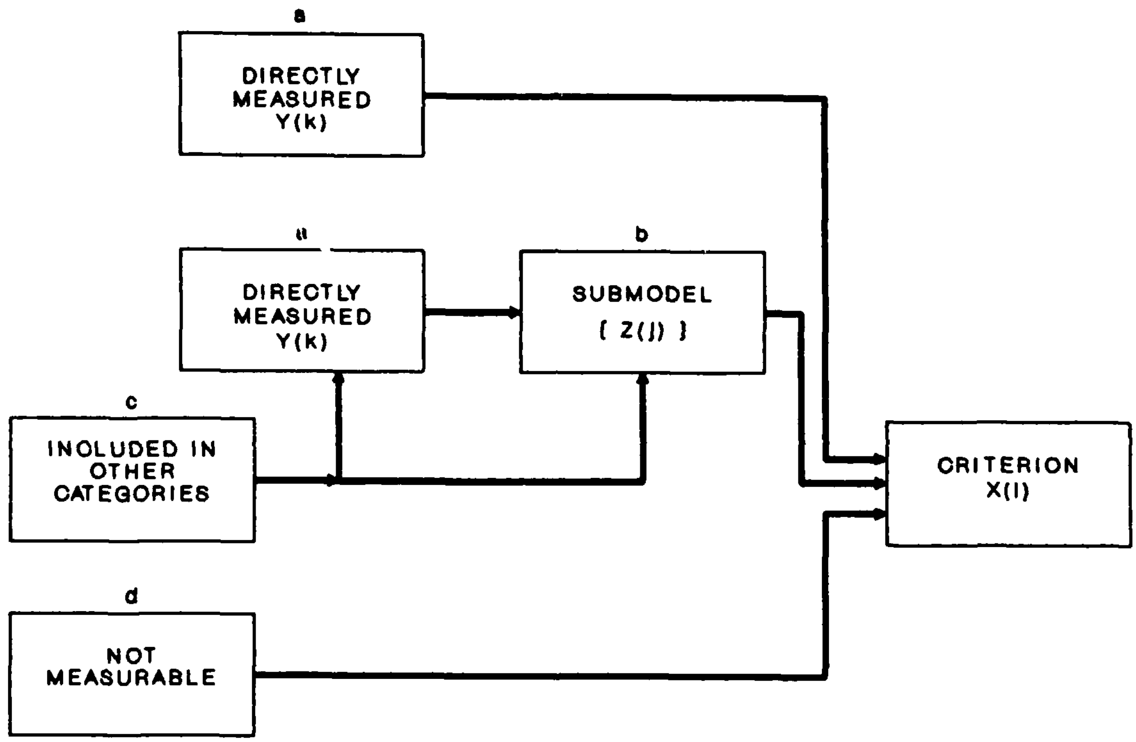


Figure 7. Elements of a Criterion For a Set of Candidate Systems (14:88)

Table 16. Criteria, Elements, and Parametric Codes

Criterion	Elements	Code
x1, Response Time	Number of calls on hold	a
	Transaction length per call	a
x2, Prioritizing	Number of Incoming Calls	a
	Conciseness of decision rules	d
	Factors of fatigue on individual prioritizing calls	d
	Number of incorrectly triaged calls	a
x3, Costs	Clerk wages	a
	Individual equipment costs	a
	Primary hardware costs	a
	Software costs	a
x3, Costs	Maintenance contract fees	a
	Support personnel wages	a
	Support hardware and supplies	a
x4, User Friendliness	Presence of user requested help features	a
	Available quick reference guides	a
	Ability to start over without having to backout	a
	Number of training hours received	a
	Complexity of software	d
x5, System Availability	MTBF (Mean Time Between Failure)	a
	MTTR (Mean Time To Repair)	a

Table 17. Code Definitions

Code	Type of Element
a	Directly measured.
b	Measured from a model that includes some of the a's.
c	Completely included in other elements.
d	Not measurable within existing resources.

complete as possible. An exhaustive list of elements is just as crucial as the criteria listing, for exclusions of elements may not be included in later decisions concerning the candidate systems. Ostrofsky also makes mention of the need for element compactness which combines, when possible, unit values of elements (14:91).

Having considered the aforementioned suggestions, the following elements were defined.

Y1: **Number of calls on hold**. This parameter is limited by the number of calls that can be stacked in the queue.

Y2: **Transaction length per call**. The length of time it takes to complete an appointment request is measured by this parameter.

Y3: **Number of incoming calls**. This parameter is a measure of calls that arrive at the hospital and are either answered, put on hold, or deflected with a busy signal.

Y4: **Number of incorrectly triaged calls**. This parameter refers to the number of calls that are incorrectly identified as to priority. Subsequently the calls are placed in the wrong category for response.

Y5: **Clerk wages**. This is the appointment clerks' hourly salary.

Y6: **Individual equipment costs**. This parameter includes items such as office furniture, standard office supplies, headsets, and phones.

Y7: **Primary hardware costs**. This parameter encompasses the computer and related hardware that are dedicated to the appointment system. This includes CRT screens, keyboards, drive units, and CPUs.

Y8: **Software costs**. Whatever computer instruction is required to satisfy the needs of the appointment system is included under this parameter. This cost may be an outright purchase, site license, lease, or rental fee.

Y9: **Maintenance contract fees**. This cost covers the contract necessary to provide maintenance and repair of acquired hardware and software.

Y10: **Support personnel wages**. Unlike the wages for clerks, this parameter may only be a ratio of the work actual obtained from the personnel. Support personnel may be involved in other duties apart from the appointment system.

Y11: **Support hardware and supplies**. This parameter accounts for the miscellaneous equipment needed for support of the appointment system. This would include printers, paper, ribbons, disks, and communication lines.

Y12: **Presence of user requested help features**. This parameter allows appointment clerks to customize their appointment system display with any needed help screen overlays available.

Y13: **Ability to start over without having to backout**. This allows a clerk to quickly escape from a potential

error-making situation instead of having to backout level by level from the current screen.

Y14: **Available quick reference guides**. The parameter refers to the availability of instructional aids that can be quickly referenced while operating a system. Such guides may include continuity folders that outline specific tasks and available options, keyboard templates, and quick reference sheets available at a glance. Availability of such tools may be in the form of integrated software features or preprinted reference guides.

Y15: **Number of training hours received**. This parameter quantifies the number of training hours a clerk receives involving the specifics of the appointment system. Training can be generalized or it may involve specific clinic detail.

Y16: **MTBF (Mean Time Between Failure)**. This parameter is "a measure of the average amount of time a given component may be expected to operate before failing" (25:539). Such a measurement reflects the reliability and dependability of the acquired equipment. Generally MTBF values are given by the manufacturer. Selecting equipment with high MTBF values should extend operation, increase confidence in the system, and increase productivity by having fewer down times.

Y17: **MTTR (Mean Time to Repair)**. This measure is "the average time required to fix a failed component ... and restore it to service" (25:539,530). The duration of repair

time can vary depending on the number of affected systems and their complexity. MTTR can provide a baseline estimate for contingency planning for the length of time manual back up services may be required. Generally, the MTTR figure is available from the manufacturer.

Some elements were coded "d" as limited resources constrain the development of parameters to measure these elements. Elements coded "d" that describe the second criterion (Prioritizing) include: conciseness of the prioritizing decision rules and the factors of fatigue on the individual who is prioritizing the calls. Complexity of software was also coded "d" and relates to Criterion x4, (User Friendliness). This element considers the nature of the software, realizing the more complex the software operation the less likely it is to be truly user friendly.

Criterion Modeling

This section begins to quantify previously subjective values. Having established a set of criteria and parameters, it now becomes possible to identify one candidate system "whose performance as identified on the scale emerging from the criteria is better than comparable performance from any of the remaining candidate systems" (14:95). Not only does a "best" candidate system emerge, it is ranked along with other systems being nsidered.

While the criteria identified are not directly measurable, the parameters selected are combined to describe each criteria.

This effort is limited by the subjectivity involved in development of mathematical functions that relate criterion to the relative parameters. Additionally estimates must be made of minimum and maximum values for each parameter as they relate to their criterion.

Response Time. Quantitatively described as the amount of time transpired until the call is answered. This criterion is defined by the following elements:

Y1: Number of calls on hold
Y2: Transaction length per call

The resulting function is illustrated in Appendix C. This function is of an increasing linear nature and relates the product of the two parameters as the total amount of time existing until a response can be made. The resulting equation for the criterion becomes:

$$x1 = (Y1)(Y2)$$

Prioritizing. This function quantifies the success of any prioritizing protocol employed. Success is dependant upon all the elements identified in Table 16 but only the following were measurable.

Y3: Number of Incoming calls
Y4: Number of incorrectly triaged calls

As the number of incoming calls increases, the probability of successfully prioritizing a call decreases. Aggravating

this problem is the number of calls incorrectly prioritized. The resulting function is a downward sloping curve that approaches zero. This model, illustrated in Appendix C, is represented by the following:

$$x2 = -0.5\ (Y3 + Y4)^2$$

Costs. This linear function is a summation of both direct and indirect costs. The criterion is defined by the following elements:

Y5: Clerk wages
Y6: Individual equipment costs
Y7: Primary hardware costs
Y8: Software costs
Y9: Maintenance contract fees
Y10: Support personnel wages
Y11: Support hardware and supplies

Those costs considered indirect are valued at proportionate rates and included in the total costs required to maintain the appointment system in an operable mode. The function is also depicted in Appendix C and the resulting equation for the criterion function becomes:

$$x3 = (Y5 + Y6 + Y7 + Y8 + Y9 + Y10 + Y11)$$

User Friendliness. This function is particularly difficult to quantify as the friendliness of a system to a clerk may be perceived differently. The criterion is defined by the following elements:

Y12: Presence of user requested help features
Y13: Available quick reference guides
Y14: Ability to start over without having to backout
Y15: Number of training hours received

Optional features are measured as either being present or not. The sum of these features is divided by the number of training hours required by either the clinic or manufacturer to make a user proficient with the system. Complex systems may have all the features of a simpler system but will require more training hours to become proficient. The result is a decreasing value in user friendliness for increasing hours of training. The function is shown in Appendix D and the resulting equation is:

$$x4 = (Y12 + Y13 + Y14) / Y15$$

System Availability. To the user or clerk, this function describes the availability of a system at any given time. The criterion is defined by the following elements:

Y16: MTBF (Mean Time Between Failure)
Y17: MTTR (Mean Time To Repair)

Using MTTR, MTBF, and time interval, Nickel suggested the following probability function to determine system availability.

$$A(t) = [a/(a+b)] + [b/(a+b)]\, e^{-(a+b)t}$$

Where a = 1/(MTTR), b = 1/(MTBF), e is the natural logarithm, and t is a time interval (12:80; 25:462). The result of this function is the number of times a system will be available during a specified time period. Stamper notes that as the time interval increases "the exponential term approaches zero and becomes insignificant" (25:462). The resulting function is illustrated in Appendix D and the

resulting criterion equation function as suggested by Stamper becomes:

$$x5 = (Y16)/(Y16 + Y17)$$

Most systems, however, are comprised of various components, each of which have their own MTBF and MTTR values. Total system availability then becomes a product of all component availability as illustrated below (12:80).

$$A(s) = A(1)A(2) \ldots A(n)$$

where

$A(s)$ = Total system availability
$A(1) \ldots A(n)$ = Individual component availability

The preceding equations and corresponding functions illustrate a pattern of behavior associated with each of the criteria. Having developed the function, the next step was to establish an acceptable range of values for which the individual criteria can assume.

Formulation of the Criterion Functions

Earlier, in Chapter 1, a problem identification analysis was performed to subjectively bound the production/consumption cycle inputs and outputs. This process of bounding continues after defining the criterion functions, to limit the parameter ranges.

After consulting with Major Shields (22), reviewing his talking paper on standards (24), and Colonel Stuart's findings (26:394), the following parameter ranges were established based upon current trends, existing data, and

preferred outcomes. Formulation of parametric ranges, is extremely important considering that the wider the range the more candidates are included and the narrower the fewer. While debating the minimum and maximum values for each parameter, it was understood that candidate systems yielding values outside of this boundary are not considered.

The first range considered involves the criterion elements and is laid out in Table 18. The 17 parameters are listed with their respective minimum and maximum values.

Having defined an acceptable range of values for each of the parameters, it was possible to construct a similar table (Table 19) of minimum and maximum values for each criterion. Using the criterion functions developed earlier, the minimum parameter values are placed into the equations, with the result of a single criterion minimum. Maximum criterion values are arrived at in the same manner. A realistic set of values had to be determined and the tables do provide a realistic range of values outside of which no candidate system was considered.

Combining Criteria into one Function. Having completed Table 18, it was possible to synthesize a function which included all the criteria. The result is a single equation that provides a scaled performance value for each candidate system.

Having developed the criteria independently of one another, it became apparent that some method of handling the

Table 18. Range of Parameters Y(k)

	Parameter Y(k)	Y(k) Min	Y(k) Max	Mean
Y1:	Number of calls on hold	0 calls	3	1.5
Y2:	Transaction length per call	1 min	5	3.0
Y3:	Number of Incoming Calls per hour	0 calls	504	252
Y4:	Number of incorrectly triaged calls	0 calls	10	5.0
Y5:	Clerk wages	$12,195	$13,248	$12,721
Y6:	Individual equipment costs/clerk	$500	$5,000	$2,750
Y7:	Primary hardware costs	$5,000	$500K	$252,500
Y8:	Software costs	$5,000	$100K	$52,500
Y9:	Maintenance contract fees/year	$150K	$400K	$225K
Y10:	Support personnel wages	$2,000	$10K	$6,000
Y11:	Support hardware and supplies/year	$500	$3,400	$1,950
Y12:	Presence of user requested help features	0	1	0.5
Y13:	Available quick reference guides	0	1	0.5
Y14:	Ability to start over w/o having to backout	0	1	0.5
Y15:	Number of training hours received	5 days	20	12.5
Y16:	MTBF (Mean Time Between Failure)	480 hrs	16,640	8,560
Y17:	MTTR (Mean Time To Repair)	1 hour	6 hours	3.5

Table 19. Range of Criteria x(i)

	Criterion x(i)	Min	Max	Mean
x1:	Response Time	0	15	7.5
x2:	Prioritizing	-50	-127,008	-63,529
x3:	Cost	175,195	1,031,648	603,422
x4:	User Friendliness	0.0	0.60	0.30
x5:	System Availability	0.9979	0.9996	0.9988

units of each criterion must be implemented. Ostrofsky warns that,

> unless some method for relating the sensitivity of the unit value of x(1) with the unit value of x(2) is used, the resulting combination of these criteria will not be meaningful. (14:113)

Since the criterion function is a method of comparing the candidate systems against each other, it not only seems fitting but essential that their units be consistent with each other. Ostrofsky suggests "identifying criterion performance as a fraction of the allowable range for that criterion" (14:114). This unitless fraction, must be multiplied by the respective criterion's relative weight (previously identified in Table 15). This criterion function is Equation 1, which will yield a criterion performance value based on the parametric values submitted.

$$CF(\alpha) = \sum_{i=1}^{n} a(i) \left[\frac{x(i) - x(i)min}{x(i)max - x(i)min} \right] \qquad (1)$$

where

$$0.0 \le CF(\alpha) \le 1.0$$

- CF(α) = Criterion value for each α (candidate system)
- n = Number of individual criteria
- a(i) = Relative weight assigned to ith criterion
- x(i) = ith criterion value
- x(i)min = Minimum value for ith criterion
- x(i)max = Maximum value for ith criterion

Substituting the appropriate values into Equation 1, results in the following criterion function.

```
CF = .24 * [(Y1*Y2)/15]
     + .19 * [(-0.5*(Y3+Y4)² +50)/(-127058)]
     + .16 * {[(Y5+Y6+Y7+Y8+Y9+Y10+Y11)-175195]/856453}
     + .22 * {[(Y12+Y13+Y14)/Y15]/.60}
     + .19 * {[(Y16/(Y16+Y17))-.9979]/.0017}
```

Analysis of the Parameter Space

Although a complex criterion function was developed, a understanding of all parameter interactions remained elusive. Attaining complete knowledge of a system may not be practical, but understanding as much of the design space as possible is. Without a complete understanding of criteria interactions, certain risks and uncertainties are present and should be minimized. Although the choice of criteria has been based on a variety of assumptions, no analysis has yet assessed their degree of interaction. Ostrofsky summarizes by stating that "the accuracy of the entire activity is dependent on many facets of the situation which may not be included in the quantification process" (14:119).

After examining the criteria it was felt that no substantive interactions were apparent between criteria. Analysis in the following areas will help to understand and minimize uncertainties and risks in the design-planning space.

Sensitivity Analysis. The purpose of this analysis is to identify the rate of change or sensitivity of parameters to the criterion function. Ostrofsky points out that such an analysis can point out "limitations of a given concept or (candidate system)" (14:121). The result is additional insight in to the planned system and eventually a better design. Those parameters altered, will result in varying

degrees of change on the criterion function value. In short,

> this will facilitate the decision making concerning any changes or adjustments that, for various reasons, may need to be made to the optimal candidate system when identified. (14:288)

To conduct this analysis, two computer runs were initiated. The first output, generated by the computer code in Appendix E, was recorded in Table 20 and demonstrated a change when one parameter was varied by a small, fixed amount (five percent) while the remaining parameters were held constant. As an initial investigative value, the mean of each parameter range was chosen as a constant from which to work. Minimum and maximum values were excluded as starting points because of the possibility for extreme sensitivity reactions.

After computing the initial criterion function value (CFV) for the parameter means, one parameter was increased by five percent. Next the CFV was recalculated with the new parameter value, the difference in CFVs noted, and a corresponding rate of change was observed.

The results showed parameters Y1 (number of calls on hold) and Y2 (transaction length per call) with the highest percentage change in the CFV. This analysis indicates that parameters Y1 and Y2 are the most sensitive to change in relation to the CFV. This indicates that any variation or change of these parameters should be considered carefully as they will produce the greatest effect on the CFV.

Table 20. Sensitivity Analysis

Y(k)	CFα	Yk mean	Change in Yk	CF'α	Changes in CFα	Pct
Y1	0.3798	1.5	1.58	.3834	.0033	.94
Y2	0.3798	3.0	3.15	.3834	.0033	.94
Y3	0.3798	15.0	15.75	.3802	.0004	.11
Y4	0.3798	5.0	5.25	.3802	.0004	.11
Y5	0.3798	12721.0	13357.05	.3799	.0001	.03
Y6	0.3798	2750.0	2887.50	.3798	.0000	.00
Y7	0.3798	252500.0	265125.00	.3821	.0023	.62
Y8	0.3798	52500.0	55125.00	.3803	.0004	.12
Y9	0.3798	225000.0	236250.00	.3819	.0021	.55
Y10	0.3798	6000.0	6300.00	.3798	.0000	.01
Y11	0.3798	1950.0	2047.50	.3798	.0000	.00
Y12	0.3798	0.5	0.53	.3805	.0007	.19
Y13	0.3798	0.5	0.53	.3805	.0007	.19
Y14	0.3798	0.5	0.53	.3805	.0007	.19
Y15	0.3798	12.5	13.13	.3777	-.0021	-.56
Y16	0.3798	8560.0	8988.00	.3819	.0021	.57
Y17	0.3798	3.5	3.68	.3775	-.0023	-.61

Parameters Y7, Y9, Y15, Y16, and Y17 also had large percentage differentiations and therefore appropriate care is required when making adjustments to these parameters as well.

Rather than using a single variance in the parameter, the second analysis varied each parameter over a range of values using a fixed increment of five percent. As before all other parameters were held constant about their means. Changing the parameter's amount over a range of values provided an investigation of CFV sensitivity at varying levels. While the computer run (program code in Appendix F) produced eleven sensitivity evaluations for each parameter (Appendix G), Table 21 summarizes for each parameter the least and greatest percentage change in the CFV.

Table 21. <u>Sensitivity Range Summary</u>

Y(k)	Least Percentage Change in CFα	Greatest Percentage Change in CFα
Y1	0.94	5.23
Y2	0.94	5.23
Y3	0.11	0.69
Y4	0.11	0.69
Y5	0.03	0.17
Y6	0.00	0.04
Y7	0.62	3.43
Y8	0.12	0.59
Y9	0.55	3.05
Y10	0.01	0.08
Y11	0.00	0.03
Y12	0.19	1.06
Y13	0.19	1.06
Y14	0.19	1.06
Y15	0.56	3.38
Y16	0.57	3.52
Y17	0.60	3.33

As expected, parameters Y1 and Y2 again showed the least and greatest percentage changes, reinforcing their significant effect on the CFV.

<u>Compatibility Analysis</u>. Having gained useful information from the sensitivity analysis, the challenge still remained to assemble the proposed system into a functional entity. "Compatibility is the orderly, efficient integration and operation of elements in the system" (14:291). Therefore, the purpose of the compatibility analysis was to ensure the subsystems would work together in a worthwhile manner. Ostrofsky suggests "examining the design parameters and noting which have the least effect on the total" CFV (14:127). The effect of this occurs when

needed changes are identified, then the alteration of parameters will commence with those previously identified as having the least effect on the CFV.

Referring to Tables 20 and 21, both show the following parameters to be the least sensitive:

Y5: Clerk wages
Y6: Individual equipment costs/clerk
Y10: Support personnel wages
Y11: Support hardware and supplies/year

If changes to the parameters are required to ensure system compatibility, then these parameters should be adjusted first since they produce the least effect on the CFV. Should these parameters not produce the desired effect then consideration must be given to other parameters with greater sensitivity values, until a suitable solution can be found.

Stability Analysis. Identifying changes and making corrections to a system will help ensure its success in the field. Understanding what the system will actually do in its environment is the subject of a stability analysis.

As stated earlier, an appointment system must meet the needs of both patients and providers. When uneven workloads cause system stress, eventually component failure may occur. Routine maintenance may be able to prevent such breakdowns, but adequate system planning would aid the designer in adjusting for such subsystem interactions that may make the proposed system susceptible to failure. This in effect is preventative thinking or actions that will preclude the effects of unforeseen disasters or untimely events.

Ostrofsky depicts such system interactions in an "m+1" Euclidean space, where m is the number of parameters (14:129). Thus the appointment system model becomes an 18 dimensional surface with the 18th dimension being the value of the criterion function itself. For each interaction between parameters there is 17 levels, each corresponding to the number of parameters involved. Such a depiction is extremely complex and beyond the scope of normal analysis.

In a more understandable 3-dimensional example, stable interactions may be represented by hills or maximum CFVs and less stable interactions by valleys or minimum CFVs. Other valid CFVs are depicted by flatter sheer planes in between the hills and valleys where interactions are highly unstable. Ostrofsky points out that having an understanding for the shape of these hills, valleys, and planes will aid the designer in his awareness of "conditions which might cause failure or major malfunctions" (14:129).

Since the criterion function itself was constructed mathematically instead of by practical observation, the function itself is a subjective indicator of performance. Consequently the criterion function cannot be used outside its design space to test system performance and is therefore limited, unless the criteria and their parameters are re-evaluated.

It may seem, that after careful analysis and development of a predictive equation, much of the system's success

is left to chance. While this may be true, the designer will, in any case, have greatly reduced the possibilities for failure or malfunction and will be better equipped to assess problems and suggest changes.

Formal Optimization

This section is the final step in choosing an optimal candidate system, one that will satisfy the needs and goals identified earlier. The candidate system chosen yields the highest CFV from among all other CFVs considered. Combining parameter values in such a way that each candidate system receives an optimal value is defined by Ostrofsky as "optimization within a candidate system" (14:134). This is done to assure a candidate system is compared in its "best light" (14:134).

The computer program in Appendix F, was run for this optimization. The program assembled 131,072 combinations of parameter values and compared the resulting CFVs. Five CF values were recorded to show any variations on parameter values and the resulting CFV. After one and a half hours of computation time the top five candidate systems were outputted and appear below in table 22.

The values of the parameters that yielded the top CFV were then used to evaluate the best candidate system from amongst the activities defined in the feasibility study.

Table 22. Optimization of CFV

Y(k)	1st	2nd	3rd	4th	5th
Y1	3	3	3	3	3
Y2	5	5	5	5	5
Y3	30	30	30	30	30
Y4	10	10	10	10	10
Y5	13248	13248	13248	13248	13248
Y6	5000	5000	5000	5000	5000
Y7	455000	455000	455000	455000	455000
Y8	100000	100000	100000	5000	100000
Y9	400000	400000	400000	400000	400000
Y10	10000	10000	2000	10000	10000
Y11	3400	500	3400	3400	3400
Y12	1	1	1	1	1
Y13	1	1	1	1	1
Y14	1	1	1	1	1
Y15	5	5	5	5	5
Y16	16640	16640	16640	16640	16640
Y17	1	1	1	1	6
CFVs	.906800	.906258	.905306	.889053	.873231

The highest CFV of .9068 suggested a candidate system from Concept III, composed of activities and alternatives A1, B3, C1, D7, E4, F7, G7, and H1.

Such a candidate system could be fulfilled by way of implementing a centralized computer controlled voice messaging hardware and software. The system would be capable of collectively routing calls, prioritizing them, and providing requested information. Voice messaging systems rely on caller inputs which take the form of Touchtone (28) telephone signals. The system could work any length of time and hold several callers in a queue, periodically informing them of further duration. The system could be programed to provide requested information

utilizing a hierarchial decision tree. Routine and followup appointments could be made by the system with more urgent and acute care passed on to actual appointment clerks.

The system would provide a very useful service to the medical center and would undoubtedly relieve much of the present congestion. Other benefits may be acquired while using such an automated system. Quinn noted that "technology, properly applied can enhance productivity, quality and economic output in the services sector" (16:50).

This concludes the formal methodology development for this study. An indepth background study on the field of voice messaging follows to further extoll the virtues and advantages of such a system. Suffice it to say, the chosen candidate system, comprised of an automated voice messaging system, will satisfy the goals and needs previously addressed.

Summary

This Preliminary Activities section defined criteria that would quantifiably assist in the selection of the candidate system. Once defined, the criteria were weighted as to their importance. This was done to identify the more important criteria.

In order to measure the criteria, parameters were developed and were used to quantify the criteria. These parameters were combined into functions and then acceptable

ranges were established to define a region of study. Utilizing the criteria function, parameter ranges, and weighted values, a single criterion function was formed.

From this equation varying parametric values were introduced with the goal of achieving the highest CFV. After selecting the optimal candidate system, any revision or change to the criteria should occur only after careful consideration of information obtained from the sensitivity, compatibility, and stability analyses.

The further aspect of system implementation is dealt with in the Detail Activities portion of the Design Methodology and is beyond the scope of this research. Such undertakings should be handled after a thorough review of system capabilities. Although new to the area of appointment systems, automated voice messaging is a viable alternative to current clerk assisted appointment scheduling. Acceptance and successful implementation of such a system requires an understanding of what voice messaging is and how it may be integrated into the field of appointment systems.

V. Chosen Candidate System Background

Having identifed a voice messaging system to fulfill the needs outlined previously, it becomes necessary to develop a general comprehension of voice messaging.

Introduction

Since AT&T's conception of the dual-tone-multifrequency technique, the Touchtone system has become an industry standard (18:120). According to Doug Mangin, Communication Relations Manager for Ohio Bell Communications, more than 82 percent of the residential telephone lines in the greater Dayton area alone currently subscribe to Touchtone service (11). This wide spread use of Touchtone service has enabled the use of telephones as remote terminals for communication with computers.

Industry Development

In 1982 VMX Inc., Dallas TX, originated the concept of using a computer to digitally record and redirect voice messages (8:c34). Referred to as voice messaging, the heart of the system entailed a computer with three unique abilities:

> 1. The ability to turn the sounds carried by a telephone wire into digital data files that can be manipulated--copied, duplicated, moved, deleted--as any other computer file.
>
> 2. The ability to turn those files back into sounds.

3. The ability to recognize and respond to telephone Touchtones. (8:c34)

One of the leading manufacturers of voice recognition computer hardware is VOTAN of Fremont California. Bruce Ryon, marketing communications manager at VOTAN, describes voice processing as: the use of human voice to communicate with computers. With it, people can access and use computers over the phone, and in areas or situations where communicating via a keyboard is not feasible. The outgrowth of the voice processing technology has generally been classified into four modes: "automated attendant, telephone answering, information center, and voice mail" (20:16).

The switchboard operator has been replaced by the automated telephone-attendant. This system responds to incoming calls with a digitized voice message asking the caller to whom they wish to speak and subsequently routing their call to that person's phone. If there is no answer, the caller is invited to leave a message (also digitally recorded) and review it before saving (8:c35). Unlike the old desk top answering machines, voice messaging systems are not on an individual's desk, but instead are centrally located for use by an entire company. Thus a single message can be sent to many individuals without having to repeat it (2:40).

Aside from the simplistic task of recording messages, many unique applications are possible using the Touchtone keypad as a data input terminal. One of the first

industries to realize this innovative potential was the banking industry.

Industry Applications

Far West Federal Savings Bank in Portland OR, was handling approximately 20,000 customer telephone inquiries a month. As the need arose to automate their routine calls, they installed INFOBOT, "a modular voice response system from Phoenix-based Syntellect Inc" (21:84). Customer access began in 1987 and the system handles 15-20 percent of the incoming customer service calls. These calls range from account balances to interest earned and cleared checks. Customer response has been very favorable and the system has been both economical and efficient (21:85).

Another early use of Touchtone banking was by the Fulton Federal Savings and Loan of Atlanta GA. Their system, activated in July 1987, allows customers to pay their bills, verify account balances, verify withdrawals and deposits, and inquire if specific checks have cleared. Fulton employees provide more informed answers with the system, generating better customer service. The two biggest advantages to such a system are convenience to the customer and control by programmers (15:108).

Recently, Wright-Patt Credit Union in Fairborn OH, also installed a telephone automation system for its customers. This automated attendant, referred to as CALL-24, handles

approximately 20,000 calls a month, offering a range of account inquiries and money transfer between accounts. Less than a year old the system has reduced customer service calls handled by account representatives and has been considered a tremendous success by the organization (13). Telephone automation is also being used as a tool for registration and scheduling of college courses. In addition to successful registration systems at Brigham Young University, Georgia State University, and Ohio State University, Rio Salado Community College in Phoenix AZ installed a system in July 1985. The system makes registration easily accessible for a scattered community college population, making it quick, simple, and convenient. Potential savings include the retention of possible students because of the convenience. Future applications include bilingual responses, "tuition calculation, recording fee payments by charge card or bank draft and student account fee balance" (17:46).

Medical Service Use

The wide range of use for voice technology has encouraged its growth in many industries. Hospital applications have been developed but do not yet enjoy widespread use. Informal telephone inquiries to five local area hospitals, in the greater Dayton OH area, revealed a common practice of manual appointment scheduling. This is unfortunate since voice processing provides a faster, more natural, and in many cases a more cost-effective means of interacting with

the automated equipment common in the healthcare industry (19:33).

The limited use of voice messaging in hospitals has been restricted primarily to multifaceted medical centers, usually military facilities. In order to gain a better understanding of voice messaging features a communications vendor specializing in voice technology was selected. Microlog Corporation of Germantown MD was chosen based on its product availability in the GSA catalog, experience with military medical facilities and unique product features. This study in no way endorses Microlog or makes any claims regarding their product or services.

One of Microlog's primary voice messaging systems is the VoiceConnect System (VCS) 3500. John Corrigan, Microlog's Major Account Executive, extolled many of the VCS 3500's unique feature. Some of these attributes include:

Outbound dialing - Useful for patient reminders, notifying about test results, or a general recall.

Positive Voice Response - Ability to handle calls originating from either rotary or Touchtone phones.

Virtual Unlimited Message Length - Limitation is by virtue of disk storage capacity.

Remote Message Changes - Stored messages and prompts can be altered by authorized users, making emergency updates possible.

Touch Tone Digit Translation - Convert Touchtone signals into verbal descriptions such as a person's name or department.

Call Queuing - System is able to inform patients of their status while on hold, giving them their position in line.

Independent Line Operation - Each phone line can be dedicated for a unique purpose within the system.

Independent Line Application - Different applications can be combined on a single line such as pharmacy refills and appointments. (29:4)

The features of the VCS 3000 and other competitive systems, show a strong potential to satisfying the expectations and needs of an appointment service. Microlog currently has a VCS system in place at both Walter Reed Army Medical Center and Bethesda Naval Hospital (4). These high volume military treatment facilities are undoubtedly benefitting from the services of a voice messaging system. Additionally, the Medical Center at Langley AFB VA is contemplating the acquisition of the VCS system establishing the product as a well known commodity within the military and medical fields.

Although Microlog's products are well known and sport many useful features, other systems exist that may be equally satisfying to the needs of an appointment system. Only adequate research and cost/benefit analysis will extract a system most useful to a particular medical center.

Voice messaging systems are being used in other ways outside of appointment systems. St. Joseph's Hospital in Denver CO, automated their meal preparation with voice processing. Significant increases in efficiency and the elimination of errors has been observed (19:34). Kaiser-Permanente Health Foundation installed a voice recognition and output system in 1986 in one southern California facility, to remind hundreds of patients of their appoint-

ments each day. After completing the calls, "the system produces a list of people contacted, noting which of them can make their appointments and which will need rescheduling" (19:33,34).

<u>Conclusion</u>

The 1980's may be considered the efficiency through automation decade. The ability to boost productivity and efficiency through voice technology gives hospitals and other service related industries the ability to reduce errors and improve customer satisfaction. Several major military medical facilities are utilizing Microlog's VCS series automated voice messaging systems in their appointment system. Aside from its many unique features the VCS 3000 improves a hospitals call answering ability and can sort calls expediously. Continued research and development will make automated appointment scheduling a reality for the hospitals of tomorrow.

VI. Conclusions and Recommendations

This study was conducted under the auspices of improving access to the appointment desk at the USAF Medical Center Wright-Patterson AFB OH. The literature suggested a need to improve appointment systems overall. Little was found, however, that dealt directly with the problem of appointment system access.

The methodology used was both an engineering-design tool and an instructional aid. In performing the latter the methodology soon became an exercise in systematically thinking through the problem. The iterative process never claimed an optimum output, but instead led the designer to a "best" or optimal solution.

To arrive at this solution required an assessment of need, organizational goals, limits, and boundaries. The method then guided the designer to a quantifiable approach to the solution. This allowed the choice of an optimal system from amongst others based on a cardinal scale. The criterion function values stemmed from descriptive criteria, their weighted importance, and expected criteria behavior or functions.

Consideration was given to the sensitivity effect certain parameters have on the CFV. Based on information obtained from the sensitivity, compatibility, and stability

analyses, recommendations were made as to the magnitude of change on the CFV from altering parameter values.

The proposed candidate system, featured a voice messaging system to solve the needs of the Medical Center's appointment system. Voice messaging has been applied in numerous endeavors including appointment systems as demonstrated by the Microlog Corporation product.

Conclusions

The information gathered from the questionnaires revealed an appointment system that did not perform satisfactorily for the Medical Center staff. Some comments were very useful and indicated specific areas of concern.

The methodology resulted in a number of criteria and associated parameters that were used to quantify the "best" solution. The parameters themselves were sometimes difficult to measure and no attempt was made to measure the more abstract ones. Likewise, some parameter minimums and maximums were also difficult to establish. Careful thought had to be given for what was desired to be minimized and what was needed to be maximized. The criterion function provided a quantifiable way to input system parameters and relate them together in an effort to rank each candidate system.

Further research into appointment systems, indeed of all medical service communications, should reveal that automated telephone attendants are but temporary solutions.

Complete interconnectivity and ultimate customer satisfaction will only come through planning and an intelligent interface. Artificial intelligence may be the necessary ingredient to solve the long range communications plans of a multifaceted health care organization.

Limitations

Parameter ranges played a significant part in the development of the criterion function. Unfortunately, time constraints prevented the accumulation of more precise values. The information gathered, however, does provide a significant look at an acceptable range of values for the parameters considered.

While the sensitivity analysis did produce some insight into parameter effects on the CFV, it was limited to varying only one parameter at a time. A more in-depth and improved simulation would be able to vary each parameter successively against each other in a 17 dimensional space. This would, in effect, vary first one, then two, and eventually all 17 parameters over a range of values and measures the sensitivity of change on the CFV. Such information would prove useful as the more detail a designer possesses the more likely he is to develop a system that will fit together smoothly.

After completing the criterion function, the objective was to find a combination of parameter values that yielded

the highest CFV. Initially a computer program was designed to evaluate, where possible, up to 10 values for each parameter. This would have required an evaluation of 3.84×10^{13} combinations. To complete such an analysis would have required a computer to solve and evaluate the criterion function 1,217,656 times per second for an entire year. This computational limitation reduced the number of parameter values to just two each, but still resulted in more than 130,000 combinations.

Recommendations

With a growing, more demanding patient population, it becomes imperative to provide adequate means for them to access the Medical Center's appointment system. At the present, implementation of automated systems is the most practical solution. Information given in the Needs analysis, points to the need for automating access to the appointment system. Linking an automated voice messaging system to the present patient database would eliminate congestion and provide a more acceptable entryway to the Medical Center's appointment system.

The need exists to further study and evaluate the remaining portion of the appointment system, where this study left off. Specifically the appointment system should be examined for enhancements and improvements once an appointment is scheduled. Questions two, three, and four of

the Questionnaire specifically address this area of study and may be used for an initial problem analysis.

Additional work remains to investigate the available voice messaging systems on the market and provide an evaluation of the most promising. The result of this could then be used for an eventual system implementation. Ostrofsky's design methodology contained a fourth section, "Detailed Activities," which dictate the steps necessary to implement a specifically chosen system. If a specific system is accepted, then adherence to Ostrofsky's Detailed Activities section could successfully implement the system.

Replication of this research may be able to redefine the criteria and associated parameters and in so doing develop a more concise criterion function. At the same time consideration might also be given to further analysis of parameter and criterion interactions. Such research would enhance the validity of this study and provide a more detailed analysis of the problem.

Summary

The selection of an optimal candidate system was a multi-step process. Each succeeding step built on the one preceding it, channeling information and specifics for evaluation and development. The resulting criterion function provided a quantifiable means to select a "best" candidate system.

While the need to improve the appointment system by way of an automated voice messaging system was substantiated, the long-term solution involves utilization of artificial intelligence programs.

While the limitations discussed prevented the development of a more precise criterion function, it was clear that what did develop provided a quantifiable means to select a single candidate system to meet the needs of the Medical Center's appointment system.

After careful evaluation of existing models it is recommended that a voice messaging system be implemented. Additional research remains to evaluate the remaining portion of the appointment system to enhance its operability. Replication of this study may provide more precise criteria and parameters and further refine the criterion function.

The complexity of appointment systems is a continuously changing problem. In a non-profit service industry, customer satisfaction becomes a measure of success. For the military professional the availability and dependable accessibility of competent medical care is necessity.

Appendix A: USAF Medical Center Questionnaire

Wright-Patterson AFB
USAF Medical Center Appointment System
Staff Interview Survey Questionnaire

PURPOSE: This study is being conducted to determine how you feel about the system used for making outpatient appointments at the medical center. It should take you approximately 5 minutes to complete this survey. The results of this survey may have a significant impact on future policy and guidance of the appointment system.

All answers to the questions should be based on your experience with the appointment system at the Medical Center and not any other experience you may have had with other appointment systems. Your answers will be combined with those of other staff members, and presented for analysis at the completion of the survey.

Your cooperation in completing this questionnaire will be greatly appreciated and will provide valuable information which may be used to make the outpatient appointment system serve you better.

CHARLES H. ROADMAN II, Col, USAF, MC
Commander

1. Which statement best describes your current status:

( ) Executive Mgmt ( ) Department Chair
( ) Supervisor ( ) Appointment Clerk

Please circle the number which best describes your feelings about each of the following issues related to the way in which the appointment system operates. High numbers indicate satisfaction and lower numbers indicate dissatisfaction. Please consider only the USAF Medical Center, Wright-Patterson AFB appointment system and not any other system you have had experience with.

Very Satisfied	Satisfied	Neither	Dissatisfied	Very Dissatisfied	N/A
5	4	3	2	1	0

2. Your ability to obtain patient and schedule information from the appointment system.

5 4 3 2 1 0

3. How satisfied are you that the appointment clerk matches the patient with the proper appointment slot?

5 4 3 2 1 0

4. How satisfied are you with being able to contact the appointment clerk when you need to?

5 4 3 2 1 0

5. How satisfied are you with the number of appointment scheduling people in your area?

5 4 3 2 1 0

6. What is your overall opinion of the appointment system used to make appointments?

5 4 3 2 1 0

7. If you could change anything about the appointment system, what would it be?

THANK YOU FOR YOUR TIME AND COOPERATION

Appendix B. Stratified Tabulated Questionnaire Results

Response range: 0 (N/A) to 5 (Very Satisfied).

2. Your ability to obtain patient and schedule information from the appointment system.

	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management (9)	33%	0%	11%	11%	33%	11%
Department Chair (7)	0%	0%	14%	14%	57%	14%
Subtotal (16)	19%	0%	13%	13%	44%	13%
Supervisor (7)	0%	0%	14%	14%	29%	43%
Appointment Clerk (11)	0%	0%	9%	9%	36%	45%
Subtotal (18)	0%	0%	11%	11%	33%	44%
COMBINED TOTAL (34)	9%	0%	12%	12%	38%	29%

3. How satisfied are you that the appointment clerk matches the patient with the proper appointment slot?

	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management	33%	0%	22%	11%	22%	11%
Department Chair	0%	0%	14%	29%	57%	0%
Subtotal	19%	0%	19%	19%	38%	6%
Supervisor	0%	0%	0%	0%	71%	29%
Appointment Clerk	9%	0%	0%	18%	27%	45%
Subtotal	6%	0%	0%	11%	44%	39%
COMBINED TOTAL	12%	0%	9%	15%	41%	24%

4. How satisfied are you with being able to contact the appointment clerk when you need to?

	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management	33%	0%	11%	22%	33%	0%
Department Chair	0%	0%	14%	29%	29%	29%
Subtotal	19%	0%	13%	25%	31%	13%
Supervisor	0%	0%	0%	0%	14%	86%
Appointment Clerk	73%	0%	0%	0%	18%	9%
Subtotal	44%	0%	0%	0%	17%	39%
COMBINED TOTAL	32%	0%	6%	12%	24%	26%

5. How satisfied are you with the number of appointment scheduling people in your area?

	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management	44%	33%	0%	11%	11%	0%
Department Chair	0%	29%	71%	0%	0%	0%
Subtotal	25%	31%	31%	6%	6%	0%
Supervisor	0%	14%	14%	14%	43%	14%
Appointment Clerk	0%	18%	9%	0%	45%	27%
Subtotal	0%	17%	11%	6%	44%	22%
COMBINED TOTAL	12%	24%	21%	6%	26%	12%

6. What is your overall opinion of the appointment system used to make appointments?

	N/A 0	V/D 1	D 2	N/S/D 3	S 4	V/S 5
Executive Management	33%	11%	22%	0%	33%	0%
Department Chair	0%	0%	43%	43%	14%	0%
Subtotal	19%	6%	31%	19%	25%	0%
Supervisor	0%	0%	29%	14%	57%	0%
Appointment Clerk	0%	9%	9%	9%	64%	9%
Subtotal	0%	6%	17%	11%	61%	6%
COMBINED TOTAL	9%	6%	24%	15%	44%	3%

7. If you could change anything about the appointment system, what would it be?

Executive Management:

1. Expand access, that is add more clerks.
2. Increase training for clerks.
3. Patients have difficulty phoning into the system and have little confidence in the computer.
4. Make some change to the waiting list.
5. Number of phone lines
6. Number of appointment clerks.

Department Chairmen:

1. Control over pre-recorded messages heard by patients when calling the appointment desk.
2. Patients need to be made aware of information phone number.
3. Improved access to the system, to include additional staff to meet peak demand times.
4. More phone lines.

Department Chairmen (continued):

5. More appointment clerks.
6. Upgrade appointment clerk positions.
7. More medically qualified appointment managers.
8. Increase manning to allow better rapport with clerk and patient.

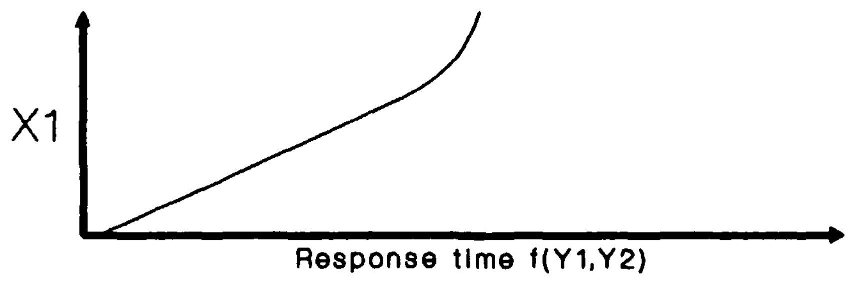
Supervisors:

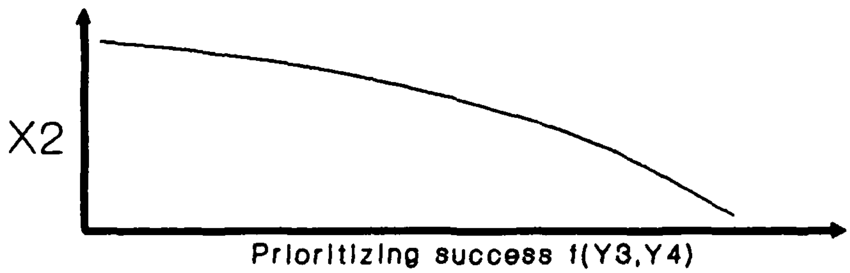
1. Enough help to cover the busy times.
2. Hire clerks at GS-4 rating.
3. Total decentralization of appointment system.
4. More personnel to meet patient needs better.
5. Complaints received concerning patients being unable to get through busy phone lines.
6. Difficult for patients to make same day appointments.
7. Computers need to respond faster
8. Another clerk on busy days would be helpful.
9. Toll free 1-800 number would be beneficial to patients calling long distance.
10. Patients wait too long on system, should either get an answer or a busy signal.
11. Something indication of what clinic is reached when put on hold.
12. Informational response to indicate best times to try calling back.
13. More flexibility, to allow providers to change or add appointment times.

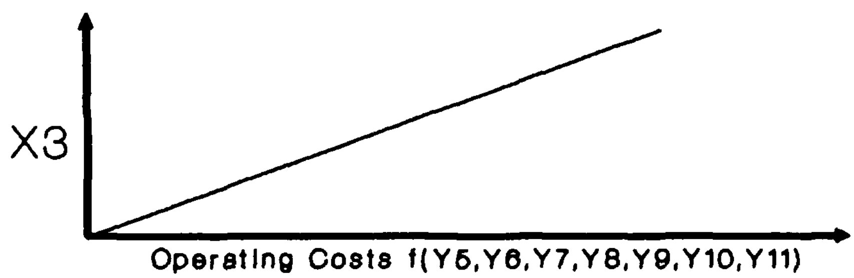
Appointment Clerks:

1. More available appointments without overbooking.
2. Appointment times need to be better aligned with problem type.
3. Allow providers to make their own follow up appointments for patients.
4. More appointment clerks.
5. Ability to make multiple appointments for a single patient.
6. Put a quite ringer on the telephones.
7. Hire temporary appointment clerks.
8. Closer coordination is needed between clinics and appointment clerks. Scheduling changes made without notifying clerks.
9. Keep clerks current on all new appointment procedures.
10. Slow computer responses, due to overloading.
11. Better telephone equipment needed.
12. Diversity, some kind of break is needed or change of pace.
13. Limit the number of information calls.

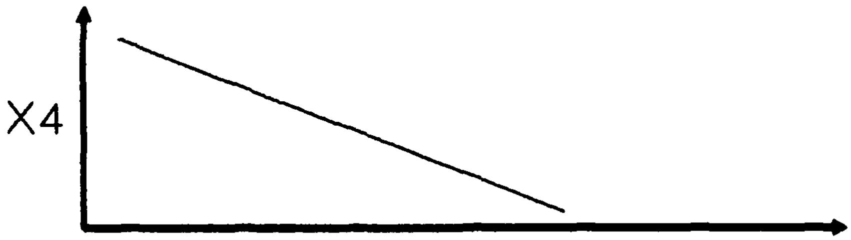
Appendix C: Graphed Criterion Functions x1, x2, and x3



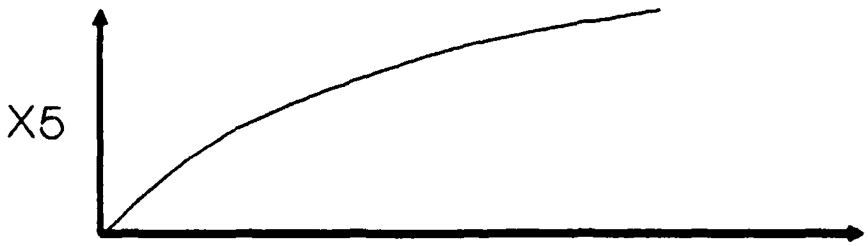




Appendix D: Graphed Criterion Functions x4 and x5



User Friendliness f(Y12,Y13,Y14,Y15)



System Availability f(Y16,Y17)

Appendix E: Source Code for Single Value Sensitivity Analysis

```
10 ------------------------------
20 REM SOURCE CODE, VERSION 1.1
30 REM SENSITIVITY ANALYSIS
40 REM FOR GRADUATE THESIS
50 REM
60 REM WRITTEN IN TURBO BASIC XL VER 1.5
70 REM (C) 1985 BY FRANK OSTROWSKI
80 ------------------------------
90 REM
100 DIM Y(20),OLDY(20)
110 LPRINT "****  SENSITIVITY ANALYSIS AT 5% ****"
120 FOR I=1 TO 17
130 Y(1)=1.5:Y(2)=3:Y(3)=15:Y(4)=5:Y(5)=12721
140 Y(6)=2750:Y(7)=252500:Y(8)=52500:Y(9)=225000:
    Y(10)=6000
150 Y(11)=1950:Y(12)=0.5:Y(13)=0.5:Y(14)=0.5:Y(15)=12.5:
    Y(16)=8560:Y(17)=3.5
160 GOSUB 320
170 OLDY(I)=Y(I)
180 Y(I)=Y(I)*1.05
190 OLDCF=CF
200 GOSUB 320
210 CFDIFF=CF-OLDCF
220 CHANGE=(CFDIFF/OLDCF)*100
230 OLDCF=INT(OLDCF*10000)/10000
240 OLDY(I)=INT(OLDY(I)*10000)/10000
250 Y(I)=INT(Y(I)*1000)/1000
260 CF=INT(CF*10000)/10000
270 CFDIFF=INT(CFDIFF*10000)/10000
280 CHANGE=INT(CHANGE*100)/100
290 LPRINT "Y";I,OLDCF,OLDY(I),Y(I),CF,CFDIFF,CHANGE
300 NEXT I
310 END
320 CF1=0.24*((Y(1)*Y(2))/15)+0.19*(((-0.5*(Y(3)*Y(4))^2)
    +50)/-127058)
330 CF2=CF1+0.16*(((Y(5)+Y(6)+Y(7)+Y(8)+Y(9)+Y(10)+
    Y(11))-175195)/856453)
340 CF=CF2+0.22*(((Y(12)+Y(13)+Y(14))/Y(15))/0.6)+0.19*
    (((Y(16)/(Y(16)+Y(17)))-0.9979)/1.7E-03)
350 RETURN
```

Appendix F. Source Code for Multiple Values in a Sensitivity Analysis

```
10 ------------------------------
20 REM SOURCE CODE, VERSION 2.0
30 REM MULTIPLE PERCENTAGE RUN
40 REM SENSITIVITY ANALYSIS
50 REM FOR GRADUATE THESIS
60 REM
70 REM WRITTEN IN TURBO BASIC XL VER 1.5
80 REM (C) 1985 BY FRANK OSTROWSKI
90 ------------------------------
100 LPRINT "****  SENSITIVITY ANALYSIS ****"
110 DIM Y(20),OLDY(20)
120 FOR I=1 TO 17
130   GOSUB 500
140   GOSUB 460
150   LPRINT "Y(";I;")","MEAN VALUE = ";Y(I)
160   LPRINT "INITIAL CF VALUE = ";CF:LPRINT
170   LPRINT :LPRINT "Yj + %Yj    CFV     CHG. CFV   %CHG"
180   PCT=1.05
190   OLDY(I)=Y(I)
200   FOR LOOP=1 TO 5
210     GOSUB 500
220     GOSUB 460
230     OLDY(I)=OLDY(I)*PCT
240     Y(I)=OLDY(I)
250     OLDCF=CF
260     GOSUB 460
270     DIFFCF=CF-OLDCF
280     CHANGE=(DIFFCF/OLDCF)*100
290     OLDCF=INT(OLDCF*10000)/10000
300     OLDY(I)=INT(OLDY(I)*10000)/10000
310     Y(I)=INT(Y(I)*10000)/10000
320     CF=INT(CF*10000)/10000
330     DIFFCF=INT(DIFFCF*10000)/10000
340     IF Y(I)>100 THEN Y(I)=INT(Y(I))
350     CHANGE=INT(CHANGE*100)/100
360     LPRINT Y(I),CF,DIFFCF,CHANGE
370   NEXT LOOP
380   IF PCT=0.95 THEN 410
390   PCT=0.95:GOSUB 500
400   GOTO 190
410   LPRINT :LPRINT
420   IF I/3=INT(I/3) THEN LPRINT CHR$(12):LPRINT
      "*****  SENSITIVITY ANALYSIS  *****"
430 NEXT I
440 END
450 ------------------------------
```

```
460 CF1=0.24*((Y(1)*Y(2))/15)+0.19*(((-0.5*(Y(3)*Y(4))^2)
    +50)/-127058)
470 CF2=CF1+0.16*(((Y(5)+Y(6)+Y(7)+Y(8)+Y(9)+Y(10)+Y(11))
    -175195)/856453)
480 CF=CF2+0.22*(((Y(12)+Y(13)+Y(14))/Y(15))/0.6)+0.19*
    (((Y(16)/(Y(16)+Y(17)))-0.9979)/1.7E-03)
490 RETURN
500 Y(1)=1.5:Y(2)=3:Y(3)=15:Y(4)=5:Y(5)=12721
510 Y(6)=2750:Y(7)=252500:Y(8)=52500:Y(9)=225000:Y(10)=6000
520 Y(11)=1950:Y(12)=0.5:Y(13)=0.5:Y(14)=0.5:Y(15)=12.5:
    Y(16)=8560:Y(17)=3.5
530 RETURN
```

Appendix G: Computer Output of Multiple Values on a Sensitivity Analysis

**** SENSITIVITY ANALYSIS ****
Y(1)   MEAN VALUE = 1.5
INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
1.575	0.3834	3.6E-03	0.94
1.6537	0.3871	7.3E-03	1.94
1.7363	0.3911	0.0113	2.98
1.8231	0.3953	0.0155	4.08
1.9142	0.3997	0.0198	5.23
1.425	0.3762	-3.6E-03	-0.95
1.3537	0.3727	-7.1E-03	-1.85
1.286	0.3695	-0.0103	-2.71
1.2217	0.3664	-0.0134	-3.52
1.1606	0.3635	-0.0163	-4.29

Y(2)   MEAN VALUE = 3
INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
3.15	0.3834	3.6E-03	0.94
3.3075	0.3871	7.3E-03	1.94
3.4728	0.3911	0.0113	2.98
3.6464	0.3953	0.0155	4.08
3.8287	0.3997	0.0198	5.23
2.85	0.3762	-3.6E-03	-0.95
2.7075	0.3727	-7.1E-03	-1.85
2.5721	0.3695	-0.0103	-2.71
2.4434	0.3664	-0.0134	-3.52
2.3212	0.3635	-0.0163	-4.29

***** SENSITIVITY ANALYSIS *****

Y(3) MEAN VALUE = 15

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
15.75	0.3802	4E-04	0.11
16.5375	0.3807	9E-04	0.23
17.3643	0.3812	1.4E-03	0.37
18.2325	0.3818	2.0E-03	0.52
19.1441	0.3824	2.6E-03	0.69
14.25	0.3794	-5E-04	-0.11
13.5375	0.379	-8E-04	-0.21
12.8606	0.3787	-1.2E-03	-0.3
12.2175	0.3784	-1.5E-03	-0.38
11.6066	0.3781	-1.7E-03	-0.45

Y(4) MEAN VALUE = 5

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
5.25	0.3802	4E-04	0.11
5.5125	0.3807	9E-04	0.23
5.7881	0.3812	1.4E-03	0.37
6.0775	0.3818	2.0E-03	0.52
6.3813	0.3824	2.6E-03	0.69
4.75	0.3794	-5E-04	-0.11
4.5125	0.379	-8E-04	-0.21
4.2868	0.3787	-1.2E-03	-0.3
4.0724	0.3784	-1.5E-03	-0.38
3.8687	0.3781	-1.7E-03	-0.45

Y(5) MEAN VALUE = 12721

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
13357	0.3799	1E-04	0.03
14024	0.38	2E-04	0.06
14726	0.3801	3E-04	0.09
15462	0.3803	5E-04	0.13
16235	0.3804	6E-04	0.17
12084	0.3796	-2E-04	-0.04
11480	0.3795	-3E-04	-0.07
10906	0.3794	-4E-04	-0.09
10361	0.3793	-5E-04	-0.12
9843	0.3792	-6E-04	-0.15

***** SENSITIVITY ANALYSIS *****

Y(6) MEAN VALUE = 2750

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
2887	0.3798	0	0
3031	0.3798	0	0.01
3183	0.3798	0	0.02
3342	0.3799	1E-04	0.02
3509	0.3799	1E-04	0.03
2612	0.3797	-1E-04	-0.01
2481	0.3797	-1E-04	-0.02
2357	0.3797	-1E-04	-0.02
2239	0.3797	-1E-04	-0.03
2127	0.3797	-2E-04	-0.04

Y(7) MEAN VALUE = 252500

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
265125	0.3821	2.3E-03	0.62
278381	0.3846	4.8E-03	1.27
292300	0.3872	7.4E-03	1.95
306915	0.3899	0.0101	2.67
322261	0.3928	0.013	3.43
239875	0.3774	-2.4E-03	-0.63
227881	0.3752	-4.6E-03	-1.22
216487	0.373	-6.8E-03	-1.78
205662	0.371	-8.8E-03	-2.31
195379	0.3691	-0.0107	-2.81

Y(8) MEAN VALUE = 52500

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
55125	0.3803	4E-04	0.12
57881	0.3808	1.0E-03	0.26
60775	0.3813	1.5E-03	0.4
63814	0.3819	2.1E-03	0.55
67004	0.3825	2.7E-03	0.71
49875	0.3793	-5E-04	-0.13
47381	0.3788	-1.0E-03	-0.26
45012	0.3784	-1.4E-03	-0.37
42761	0.3779	-1.9E-03	-0.48
40623	0.3775	-2.3E-03	-0.59

***** SENSITIVITY ANALYSIS *****

Y(9) MEAN VALUE = 225000

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
236250	0.3819	2.1E-03	0.55
248062	0.3841	4.3E-03	1.13
260465	0.3864	6.6E-03	1.74
273488	0.3888	9.0E-03	2.38
287163	0.3914	0.0116	3.05
213750	0.3777	-2.2E-03	-0.56
203062	0.3757	-4.1E-03	-1.08
192909	0.3738	-6.0E-03	-1.58
183263	0.372	-7.8E-03	-2.06
174100	0.3703	-9.6E-03	-2.51

Y(10) MEAN VALUE = 6000

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
6300	0.3798	0	0.01
6615	0.3799	1E-04	0.03
6945	0.3799	1E-04	0.04
7293	0.38	2E-04	0.06
7657	0.3801	3E-04	0.08
5700	0.3797	-1E-04	-0.02
5415	0.3797	-2E-04	-0.03
5144	0.3796	-2E-04	-0.05
4887	0.3796	-3E-04	-0.06
4642	0.3795	-3E-04	-0.07

Y(11) MEAN VALUE = 1950

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
2047	0.3798	0	0
2149	0.3798	0	0
2257	0.3798	0	0.01
2370	0.3798	0	0.02
2488	0.3799	1E-04	0.02
1852	0.3797	-1E-04	-0.01
1759	0.3797	-1E-04	-0.01
1671	0.3797	-1E-04	-0.02
1588	0.3797	-1E-04	-0.02
1508	0.3797	-1E-04	-0.03

***** SENSITIVITY ANALYSIS *****

Y(12) MEAN VALUE = 0.5

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
0.525	0.3805	7E-04	0.19
0.5512	0.3813	1.5E-03	0.39
0.5787	0.3821	2.3E-03	0.6
0.6076	0.3829	3.1E-03	0.83
0.6379	0.3838	4.0E-03	1.06
0.475	0.379	-8E-04	-0.2
0.4512	0.3783	-1.5E-03	-0.38
0.4286	0.3777	-2.1E-03	-0.56
0.4071	0.377	-2.8E-03	-0.72
0.3867	0.3764	-3.4E-03	-0.88

Y(13) MEAN VALUE = 0.5

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
0.525	0.3805	7E-04	0.19
0.5512	0.3813	1.5E-03	0.39
0.5787	0.3821	2.3E-03	0.6
0.6076	0.3829	3.1E-03	0.83
0.6379	0.3838	4.0E-03	1.06
0.475	0.379	-8E-04	-0.2
0.4512	0.3783	-1.5E-03	-0.38
0.4286	0.3777	-2.1E-03	-0.56
0.4071	0.377	-2.8E-03	-0.72
0.3867	0.3764	-3.4E-03	-0.88

Y(14) MEAN VALUE = 0.5

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
0.525	0.3805	7E-04	0.19
0.5512	0.3813	1.5E-03	0.39
0.5787	0.3821	2.3E-03	0.6
0.6076	0.3829	3.1E-03	0.83
0.6379	0.3838	4.0E-03	1.06
0.475	0.379	-8E-04	-0.2
0.4512	0.3783	-1.5E-03	-0.38
0.4286	0.3777	-2.1E-03	-0.56
0.4071	0.377	-2.8E-03	-0.72
0.3867	0.3764	-3.4E-03	-0.88

***** SENSITIVITY ANALYSIS *****

Y(15)   MEAN VALUE = 12.5

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
13.125	0.3777	-2.1E-03	-0.56
13.7812	0.3757	-4.1E-03	-1.08
14.4702	0.3738	-6.0E-03	-1.58
15.1937	0.372	-7.9E-03	-2.06
15.9533	0.3702	-9.6E-03	-2.51
11.875	0.3821	2.3E-03	0.6
11.2812	0.3845	4.7E-03	1.25
10.7171	0.3871	7.3E-03	1.92
10.1812	0.3898	0.01	2.63
9.6721	0.3926	0.0128	3.38

Y(16)   MEAN VALUE = 8560

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
8988	0.3819	2.1E-03	0.57
9437	0.384	4.2E-03	1.11
9909	0.386	6.2E-03	1.63
10404	0.3879	8.0E-03	2.13
10924	0.3897	9.8E-03	2.6
8132	0.3774	-2.5E-03	-0.64
7725	0.3748	-5.0E-03	-1.3
7339	0.3722	-7.6E-03	-2
6972	0.3694	-0.0104	-2.74
6623	0.3664	-0.0134	-3.52

Y(17)   MEAN VALUE = 3.5

INITIAL CF VALUE = 0.3798164157

Yj + %Yj	CFV	CHG. CFV	%CHG
3.675	0.3775	-2.3E-03	-0.61
3.8587	0.3751	-4.7E-03	-1.24
4.0516	0.3726	-7.2E-03	-1.9
4.2541	0.3699	-9.9E-03	-2.6
4.4668	0.3672	-0.0127	-3.33
3.325	0.382	2.2E-03	0.6
3.1587	0.3842	4.4E-03	1.17
3.0007	0.3863	6.5E-03	1.71
2.8506	0.3882	8.4E-03	2.23
2.708	0.3901	0.0103	2.72

Appendix H: Source Code for Multiple CFV Comparisons

```
10 REM ----------------------------
20 REM SOURCE CODE, VERSION 1.0
30 REM CRITERION COMPARISON
40 REM FOR GRADUATE THESIS
50 REM
60 REM WRITTEN IN TURBO-BASIC XL 1.5
70 REM (C) 1985 BY FRANK OSTROWSKI
80 REM ----------------------------
90 REM
100 DIM Y(20),OLDY(20),RESULT(10,20),TOP(5)
110 FOR Y1=0 TO 3
120 FOR Y2=1 TO 5
130 FOR Y3=0 TO 30 STEP 3
140 FOR Y4=0 TO 10
150 FOR Y5=12195 TO 13248 STEP 210.6
160 FOR Y6=500 TO 5000 STEP 450
170 FOR Y7=5000 TO 500000 STEP 49500
180 FOR Y8=5000 TO 100000 STEP 9500
190 FOR Y9=150000 TO 400000 STEP 25000
200 FOR Y10=2000 TO 10000 STEP 800
210 FOR Y11=500 TO 3400 STEP 290
220 FOR Y12=0 TO 1
230 FOR Y13=0 TO 1
240 FOR Y14=0 TO 1
250 FOR Y15=5 TO 20 STEP 2
260 FOR Y16=480 TO 16640 STEP 1616
270 FOR Y17=1 TO 6
280 GOSUB 530
290 IF CF>TOP(1) THEN TOP(1)=CF:V=1:GOTO 570
300 IF CF>TOP(2) THEN TOP(2)=CF:V=2:GOTO 570
310 IF CF>TOP(3) THEN TOP(3)=CF:V=3:GOTO 570
320 IF CF>TOP(4) THEN TOP(4)=CF:V=4:GOTO 570
330 IF CF>TOP(5) THEN TOP(5)=CF:V=5:GOTO 570
340 REM PLACE HOLDER
350 NEXT Y17
360 NEXT Y16
370 NEXT Y15
380 NEXT Y14
390 NEXT Y13
400 NEXT Y12
410 NEXT Y11
420 NEXT Y10
430 NEXT Y9
440 NEXT Y8
450 NEXT Y7
460 NEXT Y6
```

```
470 NEXT Y5
480 NEXT Y4
490 NEXT Y3
500 NEXT Y2
510 NEXT Y1
520 GOTO 750
530 CF1=0.24*((Y1*Y2)/15)+0.19*(((-0.5*(Y3*Y4)^2)+50)
    /-127058)
540 CF2=CF1+0.16*(((Y5+Y6+Y7+Y8+Y9+Y10+Y11)-175195)/856453)
550 CF=CF2+0.22*(((Y12+Y13+Y14)/Y15)/0.6)+0.19*(((Y16/
    (Y16+Y17))-0.9979)/1.7E-03)
560 RETURN
570 RESULT(V,1)=Y1
580 RESULT(V,2)=Y2
590 RESULT(V,3)=Y3
600 RESULT(V,4)=Y4
610 RESULT(V,5)=Y5
620 RESULT(V,6)=Y6
630 RESULT(V,7)=Y7
640 RESULT(V,8)=Y8
650 RESULT(V,9)=Y9
660 RESULT(V,10)=Y10
670 RESULT(V,11)=Y11
680 RESULT(V,12)=Y12
690 RESULT(V,13)=Y13
700 RESULT(V,14)=Y14
710 RESULT(V,15)=Y15
720 RESULT(V,16)=Y16
730 RESULT(V,17)=Y17
740 GOTO 340
750 LPRINT "CANDIDATE SYSTEM ANALYSIS RESULTED IN
    THE FOLLOWING"
760 LPRINT "TOP CHOICES"
770 FOR XX=1 TO 5
780 LPRINT "CHOICE ";XX;" CFV = ";TOP(XX)
790 LPRINT :LPRINT "CANDIDATE VALUES:"
800 FOR YY=1 TO 17
810 LPRINT "Y(";YY;") = ";RESULT(XX,YY)
820 NEXT YY
830 LPRINT :LPRINT
840 NEXT XX
850 END
```

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The purpose of this study was to select an optimal candidate system that would meet the needs identified. In the process the justification for selection was developed.

The study first conducted an indepth needs analysis of the problem, which was defined as the poor accessibility to the Medical Center appointment desk. Secondly, a feasibility study was completed that captured problem data and organized into a more meaningful analysis of the problem. Finally a preliminary activities phase established quantifiable criteria to assist in the selection of an optimal candidate system.

The methodology established 17 measurable parameters to quantify the criteria chosen. This quantification process assisted in the development of a single criterion function. The utilization of this function allowed for the selection of a single candidate system based on a cardinal scale. Sensitivity of the total criterion function value to each of the parameters was identified. Any changes to the chosen candidate system parameters should avoid affecting those parameters identified as having the greatest sensitivity.

The candidate system chosen relied on the use of an automated voice messaging system. A review of voice messaging technology showed the clear advantage this communications application has. While no product endorsements were made, or suggested, Microlog Corporation's VCS 3000 automated voice messaging system was reviewed as an illustration of voice messaging equipment.

Recommendations included the need for further research that would improve other aspects of the appointment system. Duplication and verification of the study itself may improve the criteria selected and the choice of measurable parameters. Additional areas of research may also be directed toward the evaluation of available commercial voice messaging systems. Implementation of any particular system was not addressed but was assumed to be a matter more appropriately left to the local commander's discretion.